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Aircraft Age-Related Degradation Study on Single- and Three-Phase Circuit Breakers

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16. Abstract

This report provides technical data and brief observations generated for a controlled series of tests on circuit breakers removed from an aging Boeing 727-232 and a McDonnell Douglas DC-10 aircraft. The test program is divided into two groups (Process 1 and Process 2). Sixty circuit breakers in Process 1 were tested for 200% and 500% current overloads. Two hundred forty circuit breakers in Process 2 were tested for voltage drop at rated current, minimum and maximum limits of ultimate trip, 150% and 200% low current overload, and 400% to 500% high current overload. The low voltage contact resistance and temperature rise were continuously monitored. This report also contains a summary of results generated by the FAA Airworthiness Assurance Nondestructive Inspection Validation Center located at Sandia National Laboratories on circuit breakers removed from three aged aircraft.

The results of the tests protocols indicated that circuit breakers installed in aircraft with extended service life will continue to protect the electrical wire provided the maintenance procedures recommended in the report are performed annually. The report also recommends proposed changes to SAE Aero-Space Standards to improve circuit protection on future aircraft.

This report also contains technical data generated by the FAA Airworthiness Assurance Nondestructive Inspection Validation Center on circuit breakers removed from three retired aircraft. The most significant result of this study is a 39% failure rate in the 114% to 138% current overload ranges. The value and impact of this study still needs to be determined.

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EXECUTIVE SUMMARY

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1. INTRODUCTION.

1.1 PURPOSE.

The purpose of the test program is to provide data needed to determine to what extent circuit breakers removed from aging aircraft have degraded from their original performance specification parameters. The data will be used to help the Federal Aviation Administration (FAA) to determine causes of breaker degradation, to determine to what extent degradation may affect the continued safe operation of the wiring component protected by the breaker, and to determine the impact of the degradation on aircraft performance.

1.2 BACKGROUND.

In response to several mishaps in which the cause was determined or suspected to be failures of the electrical interconnection system (wiring), the FAA established the Aging Electrical Systems Research Program. The program is intended to conduct research into aging electrical interconnection systems and to develop the means for insuring the continued safety of those systems in aging aircraft. Specifically, the research will determine the mechanisms, which drive the aging process, develop tools to better inspect and maintain wiring, and develop technologies that eliminate or mitigate the hazards associated with wiring failure.

In the spring of 2000, the FAA sponsored a small test program to evaluate the performance of circuit breakers removed from several retired large transport aircraft. The FAA Airworthiness Assurance Nondestructive Inspection Validation Center located at Sandia National Laboratories in Albuquerque, New Mexico, conducted the testing. Results are provided in appendix J. The results of the study indicated that a more intensive and controlled evaluation of circuit breaker aging was necessary, which is the topic of this report.

1.2.1 Components.

Generally, wiring components are expected to safely perform the intended function throughout the design life of the aircraft. It has generally been assumed that components will not normally require replacement during the design life of the aircraft. When an aircraft has been extended beyond the original design life limit, it is important to understand the aging characteristics of wiring components and to insure that the components will continue to perform safely. If the continued aging of the components degrades the electrical distribution system performance, control measures must be adopted. The measures may either control the level of degradation (which may include inspections, repairs, maintenance, and in extreme cases, complete replacement of components) or mitigate the hazards associated with the failure modes created by the degradation.

1.2.2 Inspection.

Electrical wiring components are passive in function, thus providing little or no feedback on the degree of degradation. Wiring components typically do not exhibit functional or visual signs of degradation until the electrical system no longer distributes the required information or power. Generally, there are no provisions made for regular test and evaluation beyond general visual

inspection (GVI). For some electrical components, such as circuit breakers, GVI may not be sufficient. In addition, there are no clear maintenance requirements, no means for easy inspection and, in general, no defined life limits for these devices (other than clearly recognizable failures). Just how age and environment relate to performance degradation or failure of circuit breakers is the subject of this research.

1.3 RELATED ACTIVITIES AND DOCUMENTS.

SAE Aerospace Recommended Practice (ARP) 1199, "Selection, Application, and Inspection of Electrical Over-current Protection Devices," provides circuit breaker application guidance to aircraft electrical systems designers. The basic principles established in ARP 1199 are discussed in generalities in ARP 4404, "Aircraft Electrical Installation." ARP 4404 was used as a baseline for requirements specified in Chapter 11 (Electrical Systems) of FAA Advisory Circular 43.13-1B, Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair. Discussions of the data generated by the protocol specified herein shall assume breakers were installed in the aircraft in accordance with ARP 1199. Technical definitions used herein shall also be based on definitions provided in ARP 1199. SAE Aerospace Specification (AS) 50881 (previously MIL-W-5088), "Wire Aerospace Vehicles," has been the baseline for commercial aircraft for many years. AS 50881 defined how the wiring system (wire, connectors, terminals, etc.) are assembled and installed in the aircraft. Discussion of the data herein assumes the wires and terminals attached to breakers are installed in accordance with AS 50881 guidelines.

The philosophy of ARP 1199 is that the electrical circuit protection should, in general, provide automatic protection to a single circuit and more importantly minimize smoke and fire to the electrical components, equipment, and wire. The breaker's primary purpose is to protect the wire. In general, equipment protection requires a separate protection device. ARP 1199 assumes, "circuit breakers will be applied within the electrical rating, environmental conditions, and other parameters as described in the applicable specification or specification sheets." ARP 1199 implies that the most predominate specification used for aircraft circuit breakers components is MIL-C-5809, "Circuit Breakers, Trip Free, Aircraft." The test protocol outlined in appendix D is based on MIL-C-5809.

MIL-C-5809, Circuit Breakers, Trip-Free, Aircraft, General Specification For, has been used since the late 1960s as a worldwide standard and is presently being converted to a commercial SAE AS 5809 Standard. The test protocols were performed in accordance with MIL-C-5809 test methods, except as modified by the test plan shown herein.

The test procedures used in this project were developed from procedures used by Raytheon Technical Services Company (RTSC) to qualify manufacturers to MIL-C-5809 for the Naval Air System Command Qualified Product List (QPL) 5809. The procedures used are as follows.

2110 – FAA_TERM_STRENGTH: Circuit Breaker Strength of Terminals

2012A – FAA_CLEAN: Circuit Breaker Cleaning

2012 – FAA_VISUAL_INVENTORY: Inventory, Visual Examination, and Data Recording

2097A – FAA_OP_FORCE: Circuit Breaker Operating Force

3001G – FAA_VOLTAGE_DROP: Voltage Drop at Rated Current

3005M – FAA_DWV_CLOSED: Breaker Dielectric Withstanding Voltage for Closed Breakers (Line & Load to Ground)

3005N – FAA_DWV_OPEN: Breaker Dielectric Withstanding Voltage for Breakers In The Trip or Open Position (Line to Load)

3008C – FAA_150_200%_OL: 150% or 200% Overload Calibration

3008D – FAA_400_500_600%_OL: 400%, 500%, or 600% Overload Calibration

3009H – FAA_LVCR: Low Voltage Contact Resistance for FAA Aged Aircraft Circuit Breakers

3011N – FAA_IR: FAA Circuit Breaker Insulation Resistance

3015 – FAA_MIN_TRIP: Minimum Limit of Ultimate Trip

3015A – FAA_90%_TRIP: 90% of Minimum Limit of Ultimate Trip

3015B – FAA_MAX_TRIP: Maximum Limit of Ultimate Trip

3015C – FAA_110%_TRIP: 110% of Maximum Limit of Ultimate Trip

4000G – FAA_FA_REPORT: FAA Failure Analysis Submittal to Manufacturers

4004 – FAA_XRAY: Procedure for Taking an X-Ray Radiograph of a Circuit Breaker

2. AIRCRAFT SAMPLE INFORMATION.

The circuit breakers were removed from 12 panels provided from two aircraft. Eight panels were provided from a Boeing 727-232 and four panels from a McDonnell-Douglas DC-10. Panels designated "A" through "D" came from the DC-10 aircraft, and panels designated "E" through "L" came from the B727-232 aircraft.

Photographs of both the front and back of each panel (see appendix A) recorded the physical conditions of the panels. The overall conditions of the panels were good, although some panels were relatively dirty compared to the others.

The aircraft deployment history, provided by the FAA, is included in appendix A. The DC-10 aircraft's first flight was June 6, 1975 and averaged 2.84 hours flight time per cycle. The aircraft was parked for modifications in November 1999. It is assumed that the panels were removed in the spring of 2001, just prior to their delivery to the RTSC test facility. The B727-232 aircraft's first flight was April 3, 1974, and averaged 1.13 hours flight time per cycle. The aircraft was retired in October 1999. It is assumed these panels were also removed in the spring of 2001.

2.1 CIRCUIT BREAKER SAMPLE INFORMATION.

The circuit breakers were sampled from the panels in accordance with the guidelines provided in appendix B. An inventory and physical examination record of each breaker sampled from the panels is also provided in appendix B. The information includes a visual description of each breaker and all associated panel or wiring information. Typical information, such as circuit breaker manufacturer's part numbers, which are coded (see appendix I), date codes, circuit identification numbers, circuit breaker terminating wire and terminal conditions, etc., were recorded.

Each circuit breaker sample was assigned a unique specimen number in accordance with the following format.

A B 203

Panel Number — A

Amp Rating — B

Assigned Circuit Breaker Number — 203

Three-phase circuit breakers are three, single-phase circuit breakers bonded together with a single reset button. Three-phase circuit breakers were recorded as three, one-phase circuit breakers for sampling purposes. To distinguish the phases, the sample number in the example above would be AB203A, AB203B, and AB203C. The last letter on the sample number represents each phase (A, B, and C).

When warranted, photographs were taken. The photographs were assigned a unique number as follows.

AB203 V 1

Specimen Number — AB203

Photograph (Visual) — V

First Photograph of AB203 — 1

2.2 CIRCUIT BREAKER REQUIREMENTS AND PART NUMBER CODES.

Three circuit breaker manufacturers and 20 different part number families were included in the test program. Each part number family was coded with an alpha character (i.e., A, B, C, etc.) followed by the breaker's ampere rating (i.e., -5, -10, -50, etc.). Within a family of parts, there may be various ampere ratings. Many of the part numbers have different performance

requirements. A list of the coded part numbers and the specification performance requirements for each breaker is provided in appendix C.

3. TEST PROTOCOL.

3.1 TEST PROTOCOL PROCEDURES.

The FAA developed the test protocol in conjunction with the circuit breaker manufacturers. The protocol is based on the MIL-C-5809 specification requirements. The MIL-C-5809 specification has been accepted as the worldwide circuit breaker standard since its conception. The test protocol outlined in appendix D required 300 breakers be divided into two test groups. Twenty percent (60 breakers) were tested in accordance with the Process 1, and 80 percent (240 breakers) were tested in accordance with the Process 2.

Each x-ray photograph was designated with the following code.

AB201 WX 1P 24A

Specimen Number — AB201

Wide X-Ray View — WX

Process 1 — 1P

Process 1 Test Block — 24A

When warranted, the samples were submitted to the manufacturer for failure analysis. Each sample had a designated failure analysis report number. The failure analysis report number was designated as follows.

AB201 -P1 B14

Specimen Number — AB201

Process 1 or 2 — -P1

Process 1 or 2 Test Block — B14

3.2 TEST PROTOCOL PROCEDURE DEVIATIONS.

Deviations from the test protocol outlined in appendix D were required. The following paragraphs discuss the deviations in detail.

3.2.1 Low Voltage Contact Resistance.

The Low Voltage Contact Resistance (LVCR) test was initially performed with a constant-current power supply using an open-circuit, 26-volt direct current. This approach was used to minimize anticipated circuit variables that would need adjustment during the test, to reduce expected test time, and to meet the precise current requirement of 200 mA. A point paper, provided in appendix D, was written to demonstrate that a constant-current approach would provide the same results as the test method specified in the Process 1 and Process 2 procedures. During the LVCR modified testing, it was noted that the constant-current approach provided initial current surges that open the 0.5 amp breakers. The open-circuit voltage was reduced to 1.0 volt to minimize the surges, but the 1.0-volt value was insufficient to overcome the contact resistance in large amp breakers. Even at 1.0 volt, a slight surge was also noted. The LVCR circuit was then setup in accordance with Process 1 and Process 2 procedures. The current surges were virtually eliminated, and a current of 200 ±0.100 mA was maintained. Although, theoretically, the constant-current approach is valid and there should be no affect on the subsequent 200% and 500% current overload tests, a partial group of new samples was removed from the panels and subjected to the LVCR test in accordance with Process 1 procedures. For the Process 2 protocol, all the LVCR tests were performed in accordance with the original test procedure. The current value was recorded after the last cycle of the LVCR voltage drop value was recorded.

3.2.2 Button View X-Rays.

The test procedure specified x-ray photographs be taken of each breaker in three axes. The x axis (wide side view) and the y axis (narrow side view) were x-ray photographed when required by the procedure. During the initial x-ray investigation, it was found that the z axis (button end view) provided little or no distinguishable information. As a result, the "button view" was only taken when a failure occurred.

3.2.3 Process 1 and 2 X-Rays.

In Process 1, each x, y, and z axis was exposed to a 90-pulse x-ray energy of 3.1 milliroentgens. In Process 2, each x and y axis was exposed to 90 pulses, and the z axis was exposed to 396 pulses of energy. The increased number of pulses in the z axis provided a clearer internal view of the circuit breaker.

3.2.4 Process 2 Block 20 Correction.

Process 2 has a missing decision test block and a failure analysis block after test block 20 (dielectric test/terminal-to-ground). This report presumes that the missing decision blocks would be designated 20a and 20b respectively.

3.2.5 Process 2 Block 47a Correction.

Test block 47a presumes the breaker to be in an open position after the minimum limit of ultimate trips required by test blocks 44 or 44a. The minimum limit of ultimate trips requires the breaker to remain in a closed position after completion of the test. If the breaker opens, it is

considered failed and submitted to test block 46 for failure analysis. In order to perform the required test block 47a test, the breaker would have to be manually opened then closed to measure the reset forces. Opening and closing the breaker, except when specified, violates the protocol, thus test block 47a was removed.

3.2.6 Process 2 Unused Test Blocks.

Although not a direct protocol deviation, numerous test blocks in the test protocols were not performed because all the circuit breakers passed prior test requirements. Further information on when these test blocks were not used is provided in section 4.

3.2.7 Voltage Drop and Temperature Rise Monitoring.

The test procedure specified the voltage drop and temperature rise of the breaker to be continuously monitored during the test program. The procedure did not specify how this information was to be reported. Since the maximum voltage drop and maximum temperature rise are the most significant result of these measurements, only the maximum values were reported.

3.2.8 Current Overload.

Process 1 test blocks 6 and 12, as well as test blocks 55 and 59, presume that all circuit breakers would have 200% and 500% current overload requirements. As indicated in appendix C, this is not the case. The current overload percentages used were in accordance with the circuit breaker's specified requirements, and those values were recorded in appendix F.

Detailed comparisons of the circuit breaker performance must take into account the variation in current overload requirements.

3.2.9 Three-Phase Breaker.

In some cases, the test requirements specified in appendix F for the three-phase breakers require one phase (one of three tandem breakers) to maintain a different current overload than for the other two phases (two of three tandem breakers). The requirement does not specify which of the three breakers (A, B, or C) should be tested at the higher overload current. It is presumed that the high current overload requirement must be applied to all three of the phases in order to verify that any one phase overload will activate the breaker. To perform the test as specified, would require three sets of power supplies and timers wired in parallel with an activation switch that would turn the current on for each phase at the same time. The test would also triple the number on times needed to complete the test blocks. To minimize the impact on cost and schedule, the test was performed at the maximum current overload for all three phases at the same time. The test result reported in paragraph 4.3.8 indicates that the presumption is acceptable.

3.2.10 Terminal Strength.

The "strength of threaded parts" test, which includes "strength of terminal" (paragraph 4.7.5.2 of MIL-C-5809), was not included in the original test protocols. As a result of visual observations

and preparation of samples, it was determined the properties of the circuit breaker terminals should be examined. The test was performed on the breakers after all other protocol requirements were completed. The results were recorded as part of the physical inventory data and are provided in appendix B.

4. DISCUSSION.

4.1 BASIC CIRCUIT BREAKER CHARACTERISTICS.

There are several different designs of circuit breakers, but the most commonly used type is the thermal circuit breaker that depends on a thermal-sensing element to release. Typically, the sensing element is a bimetal strip, which opens the electrical circuit at a predetermined calibration point based on a temperature rise caused by load current heating. Since the breaker is a thermal reactive device, the calibration will also depend upon the heat sink connected to the breaker terminal (i.e., conductor size, electrical busses, etc.), and the breaker mounting location (i.e., proximity of other breakers, components, panel size, etc.). The circuit breaker specification will specify the calibration characteristics at specific temperatures. The three most common temperature points are at room ambient (25°C), the lowest operating temperature, and the highest operating temperature designed for the breaker in free air. The electrical system designer must take into account the change in calibration due to heat sink characteristics surrounding the breaker in application and the temperature environment of the circuit breaker location.

The electrical designer must choose a circuit breaker rating that matches the wire size the breaker is trying to protect. If the wire size is too small or too big for the breaker, the heat sink characteristics of the wire will shift the calibration curve up or down, respectively. If the wire is too big, the breaker will respond more slowly to a current overload, thus inadequately protecting the wire. If the wire is too small, the breaker will open earlier than designed, potentially causing electrical system malfunctions. Although it is generally not recommended, when multiple wires are used on the same breaker for protecting noncritical circuits, the breaker must be chosen to protect the smallest wire size connected to the breaker, and the heat sink characteristics caused by the multiple conductors must be taken into account. This is not the only reason, but it is one of the principle reasons why wire is always design-controlled and is always replaced with the same size wire. Any modification by the aircraft user, involving circuit protection, must consider the heat sink characteristics of the breaker in order to prevent safety problems.

If the protection requirement of an electrical circuit cannot tolerate large changes in the calibration curves of the breaker, due to changes in the temperature surrounding the breaker location, the electrical designer should consider using a temperature compensated thermal circuit breaker. The temperature-compensated thermal circuit breaker typically has an additional sensing element that minimizes distortion in the calibration curve due to external temperature surrounding the breaker. Additionally, the performance characteristics of single-phase, temperature-compensated thermal circuit breakers are typically specified to higher application temperatures, due in part to this temperature compensation mechanism. The calibration curve of a temperature-compensated thermal circuit breaker generally allows for less variation due to ambient temperature changes than for a non-temperature-compensated thermal circuit breaker.

Temperature-compensated breakers have been more widely used in recent years to protect the electrical wire, and were not originally designed into the aircraft, which were tested in this program. The use of temperature-compensated thermal breakers is a choice of the design engineer, but is generally consistent across a platform. It is expected that since most applications typically use wire well below the temperature and current ratings, the wire can tolerate slightly wider calibration curves that may be present with the temperature-compensated thermal circuit breaker.

Most breakers evaluated in this test program are non-temperature-compensated thermal circuit breakers. ARP 1199 provides guidelines on how to take into account application of the circuit breaker. The calibration characteristics at 25°C for each breaker tested are provided in appendix C.

4.1.1 Circuit Protection.

The circuit protection of an electrical system is accomplished by controlling the following three major circuit breaker performance characteristics.

a. Voltage drop at rated current. The electrical designer must consider the total voltage drop at a rated current for each electrical circuit. This includes the electrical distribution system (wire, connector, splice, etc.) and the circuit breaker. The voltage drop must not exceed the voltage loss permitted to properly operate the electrical load. Typically, the wire size is conservatively chosen at 50% of its rated current capability to minimize circuit voltage loss effects and current overloads. In other words, the bigger the wire size the smaller the voltage loss. The designer must balance the voltage loss tolerance against the added weight and required space needed for a bigger wire. The required voltage drops for the breakers tested ranged from 0.15 to 2.0 volts (see appendix C).

b. Minimum and maximum limit of ultimate trip. The circuit breaker minimum ultimate trip limit is designed to keep the electrical circuit closed during periods of slightly increased load current. The circuit breaker maximum limit of ultimate trip limit is designed to open the circuit to protect the wire from high steady-state load current. The minimum ultimate trip limit prevents the circuit breaker from tripping for at least one hour when a slightly increased steady-state load current (typically 115% increase) is applied. The maximum ultimate trip limit causes the breaker to trip within 1 hour when a steady-state high current (typically 138% increase) is applied. The ultimate trip characteristic varies for different type breakers to accommodate different load requirements. The tested circuit breaker's ultimate trips varied from 105% to 115% for 1-hour minimum trip limits and 138% to 145% for less than 1-hour maximum trip limits (see appendix C). Because the breakers are thermal circuit monitoring devices, the ultimate trip limits will drift with time and the number of encountered on and off cycles. This is commonly known as the circuit breaker's endurance requirement. Typically, this drift is a ±10% deviation from the initial ultimate trip limit. The designer must accommodate this drift, if the breakers are to be applied for the life of the aircraft.

c. Overload current trips. The current overload requirements are designed to prevent nuisance trips caused by short duration current load surges, while at the same time,

protect the wire from current overload caused by direct shorts. The breaker will stay closed for a very short period to accommodate a current surge but open quickly enough to protect the wire. Typically, current overloads are performed at 200% and 500% of rated circuit breaker current. The lower limit typically maintains the breaker in a closed position for a longer period than does the higher limit. In some cases, the circuit breaker is designed with only a lower overcurrent trip requirement. The tested breakers had 150% and 200% lower limits with trip times ranging from 2 to 70 seconds. The upper limit of the tested breakers ranged from no limit to 600% with trip times varying from 0.16 to 15 seconds (see appendix C).

4.1.2 Circuit Breaker Cycling.

A circuit breaker is design to provide some on and off circuit characteristics, but it is not recommended to be used as a switch. A circuit breaker typically requires 2,500 on and off cycles with an inductive load, 5,000 cycles with a resistive load, or 10,000 cycles with no load. A switch is typically designed for endurances four times that of circuit breaker on and off cycles. If a circuit requires on and off action, the electrical designer should provide an electrical switch.

4.1.3 Calibration Test Temperature.

To achieve repeatable results, calibration tests must be performed under controlled temperature conditions. Calibration characteristics will vary slightly depending on the test temperature. In this project, all calibration tests were performed at 25° ±2°C. Circuit breakers with smaller amp ratings are more sensitive to calibration test temperatures than larger rated breakers. MIL-C-5809 has a very detailed test procedure including a "still" air control box to permit precise calibration measurements at specific temperatures. Schedule and cost did not permit the tested breakers to be performed individually at the precise temperature of 25° ±0°C and at zero airflow conditions.

4.1.4 General Assumptions.

The following general assumptions were used to analyze the results of the test protocols.

a. The circuit breakers were installed in the aircraft in accordance with ARP 1199.

b. The circuit breakers performance characteristics were established in accordance with MIL-C-5809 test methods.

c. The circuit breakers' calibration characteristics deviate insignificantly for a temperature change of ±2°C and in low airflow conditions.

d. Wires attached to the breakers were installed in accordance with AS 50881 (previously MIL-W-5088).

e. The wide variety of tested breakers typically represents the types of breakers used in aging commercial aircraft.

Specific detailed assumptions are included for each test discussion.

4.2 VISUAL OBSERVATIONS.

The following significant observations were noted from the visual inspections.

4.2.1 Contamination.

Appendix B data indicate that roughly 50 percent of the circuit breakers removed from the panels were exposed to dust or small particles. In most cases, the foreign or extraneous material was easily removed from the breakers. The data also indicated 11 breakers from two panels were exposed to some type of liquid as well as dust and small particles. Three breakers (1 three-phase breaker) were exposed to what appears to be copper particles. Some panels are dustier than others. The contamination may have caused circuit breaker IE228 to fail voltage drop at rated current although this could not be established conclusively (see appendix F). Seven breakers appeared to be new (very clean), although the breakers had old date codes.

4.2.1.1 Assumptions.

The assumptions for the contamination results are.

a. The dust and debris accumulated over time after aircraft delivery.

b. The liquid and copper particle exposures occurred during maintenance, since it was found with the dust and small particles.

c. The panels with the most contamination were overhead panels that provided traps for dust and small particles.

d. The breakers that appeared to be new were replaced after the majority of dust or small particle exposures already occurred.

4.2.1.2 Conclusions.

Maintenance manuals do not clearly specify that panels be routinely cleaned and protected when exposed to maintenance activity behind or above the panels.

4.2.1.3 Recommendations.

ARP 1199 states that unsealed circuit breakers exposed to contamination may develop voltage arc-over, current seepage, internal corrosion, and dry closure problems. The aircraft circuit breaker installer and maintenance personnel must take into account the impact of these issues. Although the overall results of the protocols indicated contamination has little affect, the following actions are recommended.

a. Aircraft maintenance manuals should include clear instructions on how to protect the panels during maintenance actions.

b. Maintenance schedules should be established to vacuum and clean the rear of panels at least once a year.

4.2.2 Terminal Lug Applications.

Appendix B data indicate that a significant number of breakers may be protecting multiple circuits. There were 142 wires, each with different circuit identification, attached to the 316 breakers that were evaluated. Many of the dual lug terminations were probably bussed circuits connected on the line side of the breakers and, thus, do not represent multiple circuits. Many of the lugs containing two wires had two different size conductors. In two cases, a terminal had three wires, and in one case, a terminal had four wires. A summary of the results is provided in table 1. The summary is based on the circuit breaker panel designations. The circuit information is grouped into five categories. Depending on amp rating, the categories would include signal and power circuits.

TABLE 1. MULTIPLE CIRCUITS DETAILS

Circuits Category	System Types Being Supported		Breaker Termination Method Load and Line Side	Notes
Passenger	Lights Gallery Telephone	AMPL Bty Air Conditioner Service	2 Lug/Terminal: 5 2 Wire/Lug: 32 3 Lug/Terminal: 2	(1)
Fire	Agent Body/Well Gage	Extinguisher Detection	2 Lug/Terminal: 3 2 Wire/Lug: 2	
Engine	Gage Trim Fuel	Ignition Generator	2 Lug/Terminal: 0 2 Wire/Lug: 16	(1)
Flight	Trim Land Gear Pressure Window Yaw Pitch	Wiper Navigation Communication Auto Pilot Stick DIR	2 Lug/Terminal: 8 2 Wire/Lug: 22 4 Wire/Lug: 1	(2)
Instruments/ Miscellaneous	Gage Sensor Radio Service Changer	Pump APU DME TR Switch	2 Lug/Terminal: 6 2 Wire/Lug: 25 3 Lug/Terminal: 2	(1) (2) (1)

(1) Includes one three-phase companion-trip, multiple-pole breaker with two lugs or one lug with two wires on three of the phase terminals (six possible circuits).

(2) Includes one three-phase companion-trip, multiple-pole breaker with two wires on one of the phase terminals (four possible circuits).

4.2.2.1 Discussions.

FAR 25.1357 clearly states each circuit for essential loads has an individual circuit breaker, but one breaker is not required for all types of circuits (i.e., string of lights). The philosophy of ARP 1199 states that "For reliable circuit protection, the design should provide automatic protection that will limit the fault to a single circuit..." The scope of ARP 4404 states that, "it is desirable that all circuits, including emergency circuits be equipped with an appropriate protective device." Both of these documents imply each circuit should have its own breaker, especially flight critical circuits. Unfortunately, neither ARP 1199 nor ARP 4404 provides additional guidance on when multiple circuits on a single breaker should be used. The guideline needed for determining how to crimp multiple conductors in the same terminal is not included in AS 50881. The SAE AE-8 committee responsible for AS 50881 is now addressing this issue with a draft ARP 5576, "Multi-Wire Crimp Terminations, Recommendations For." There are no guidelines on how to mount multiple terminals on a single breaker in AS 50881 or AS 5809. AS 5809 defined the breaker's type of screw and the strength of the terminals. These parts of the breaker may be impacted by multiple lugs, as well as the operation of the breaker as discussed in section 4. Table 1 results indicate there is a high probability that some circuits are attached to breakers with other circuits.

4.2.2.2 Assumptions.

The assumptions for multiple-circuit applications on single breakers are:

a. The choice of multiple wires in the same terminal is based on the total circular-mil-area of the conductor range permitted for the terminal crimp barrel.

b. The choice of circuit breaker for multiple-circuit applications is based on the smallest wire being used in the terminal lug.

c. The applications of the breakers are in accordance with FAR 25.1357.

4.2.2.3 Conclusions.

A detailed circuit analysis would need to be performed to verify multiple circuits are monitored and to determine the impact of multiple circuits on each breaker. This type of analysis is beyond the scope of the test program.

4.2.2.4 Recommendations.

To address multiple circuits on a single breaker, the following actions are recommended.

a. Request the SAE AE-8 committee, who is responsible for ARP 1199 and ARP 4404, to develop clear guidelines on when multiple circuits on the same breaker should and should not, be permitted.

b. Request the SAE AE-8 committee, who is responsible for AS 50881 and AS 5809 (formerly MIL-C-5809), to define when and how multiple wires in one lug or multiple lugs on one terminal should be applied to circuit breakers.

4.2.3 Circuit Breaker Interconnecting Components.

The physical condition of the circuit breaker terminals, mechanical locking hardware (lugs and wires), and the electrical components are summarized in tables 2 through 4 respectively.

4.2.3.1 Discussions.

4.2.3.1.1 Circuit Breaker Terminals.

The most significant result shown in table 2 is darkening breaker terminals indicating excessive heating and signs of electrical arcing indicating loose terminals. The darkened areas may be due to chemical oxidation, which can occur when the materials are exposed to high temperatures. Metal oxides are often nonconductive or semiconductive films that increase the resistance or voltage drop of the circuit, in turn increasing the potential for localized resistive heating. Some of the worst-case examples are shown in photographs JD247V1, CD071V2, and CD071V4 in appendix A, but insufficient evidence was present to indicate why the overheating or arcing occurred. A breaker would detect the excessive heating, only if sufficient heat was transferred to the breaker to cause the current element of a thermal breaker to open according to the calibration curve. A temperature-compensated thermal circuit breaker element may not be opened until much higher temperature rises occur. The calibration curves of temperature- and non-temperature-compensated breakers are often very similar, although depending on the location of the heat source, in relation to the compensating element, the temperature-compensated breaker may be a little less sensitive to some low level or extremely short heating events. It should be noted that varying levels of discoloration are expected under normal operating conditions. There were signs of some corrosion on several breakers, but the corrosion appeared to be insignificant compared to the number of samples inspected. The loose terminals noted for one manufacturer (CBMB) were due to the lack of epoxy between the terminal and the breaker housing. Nonepoxy terminal breaker types are no longer manufactured.

TABLE 2. CIRCUIT BREAKER TERMINALS CONDITION

Observations	Number of Incidents(1)
Loose(2)	10
Corroded/Black Speckle	10
Black/Arcing/Discolored	26
Clinch Nut Broke/Corroded	4

(1) Total number of terminal incidents (may include two terminals on one breaker.
(2) Terminals not epoxy bonded to case (only manufacturer CBMB).

4.2.3.1.2 LJ295 Circuit Breaker Case.

The circuit breaker sample LJ295's case cracked when mounting the test leads with an electric screwdriver. The screwdriver may have applied too much torque on the terminal. As a result of this occurrence, the breaker was replaced with another sample and all test leads were firmly tightened to the circuit breaker terminals by hand from that point forward.

4.2.3.1.3 Circuit Breaker Terminal Strength.

The "strength of threaded parts" test that includes "strength of terminal" (paragraph 4.7.5.2 of MIL-C-5809) were not included in Process 1 or Process 2 protocols. Because of the results of table 2 and the failure of LJ295, a terminal strength test was performed on 16 specimens. The results were recorded with the physical inventory in appendix B. All breakers withstood the compression force without damaging the housing. The threads on nine breakers stripped, and the housing on two breakers cracked when the minimum required torque load was applied. A quality issue or an aging issue, or both, may have caused the failures.

4.2.3.1.4 Circuit Breaker Electrical Hardware.

The most significant results noted in table 3 are the securing hardware not specifically designed for the breaker and the inconsistent application of the hardware. In some cases, not all, the required hardware was used. Cross threading of the circuit breaker terminal will cause the lug to become loose, see photograph HD182V3 in appendix B. Stripped terminal thread will also cause lugs to become loose, but none were noted during the physical inspection. Loose lugs can cause hotspots and over heating at the terminal/lug interface, similar to those shown in photographs JD247V1, CD071V2, and CD071V4 in appendix B.

TABLE 3. CIRCUIT BREAKER HARDWARE CONDITION

Hardware Issue	Number of Incidents(1)	Observations(2)
Screws	12	- Stainless Material - Brass Material - Short Length - Flat Head - Cross Threaded - Dark Color
Flat Washers	41	- Washer Against Terminal Not Lug (20) - Washer Not Specified by MIL-C-5809 (21)
Lock Washer	15	- Lock Washer Broken (7) - Lock Washer Under Lug (1) - No Lock Washer on Terminals (7)
Circuit Breaker Washer/Separator (Heat Shield)	1	- Heat Shield Missing

(1) Total number of terminal incidents (two may be on same breaker).

(2) Assumes all breakers are standardized with MIL-C-5809 screw (typically MS31957-41) and lock washer (typically MS35338-137) for each terminal.

4.2.3.1.5 Circuit Breaker Electrical Component.

The most significant result noted in table 4 is the misapplication of terminal lugs. The number of misapplications is small compared to the number of circuit breakers inspected, but the impact on the electrical system could be significant. Crimping the conductor with the wrong size lug can cause heating of the lug, wire conductor and insulation, and the circuit breaker terminal and internal components. Crimping insufficient strands can also cause hotspots and possible separation of the wire conductor.

TABLE 4. ELECTRICAL DISTRIBUTION COMPONENTS

Electrical Component	Number of Incidents	Observations
Terminal Lug	6	- Dirty (4) - 16 AWG Wire in Terminal Size (18-22/Red) - 3 Strands of Wire Crimped to a Load side Lug
Wire	13	- Numerous Wires Dirty - New Wires (7) - Red Wires (1) - Translucent Gray (1) - Gooey Substance (4)

4.2.3.2 Assumptions.

The assumptions for the interconnecting component results are:

a. The circuit breakers were originally connected to the lugs, using the securing hardware provided by the breaker manufacturer.

b. The original circuit breaker securing hardware is the standard hardware specified in MIL-C-5809 related drawings, which are one MS31957-41 screw and one MS35338-137 lock washer for each terminal post.

4.2.3.3 Conclusions.

The conclusions based on the interconnecting component results and assumptions are:

a. Aircraft maintenance manuals do not clearly specify that securing hardware should be replaced with identical parts, and there is no established process to permit substitutions until such time that the identical part can be added.

b. Aircraft maintenance manuals do not require routine inspection of circuit breaker panels to examine for loose, misapplied, or broken securing hardware and faulty electrical components.

c. Aircraft maintenance manuals do not require inspection of circuit breaker panels for signs of overheating or arcing of electrical circuits.

d. Aircraft maintenance manuals do not provide cautionary notes in regards to cross threading or over torquing mounting screws.

4.2.3.4 Recommendations.

The recommendations based on the results, assumptions and conclusions for interconnecting components are:

a. Establish routine maintenance schedules to inspect the back of circuit breaker panels for misapplied interconnecting hardware.

b. Change the aircraft maintenance manuals to include the following:

   1. Examine for loose, broken, or misapplied securing hardware.

   2. Provide guidance on what to do when signs of overheating or arcing are observed.

   3. Clearly define circuit breaker securing hardware and require identical replacement, unless there is a process permitting temporary substitution, until the part can be properly replaced.

   4. Provide cautionary notes to prevent cross threading or thread stripping and to require circuit breakers to be completely replaced when such incidents occur.

   5. Change ARP 1199, paragraph 5.8.1.b.4, to recommend circuit breaker terminal securing parts be replaced with identical parts and not permit substitutions without a process for appropriate replacement at a scheduled maintenance period.

4.2.4 Date Code Variability.

4.2.4.1 Discussions.

The circuit breaker date code methodology varied from manufacturer to manufacturer. In some cases the date, which is typically four digits, is provided with the week or month first, followed by the year. In other cases, the year and the week or month was reversed. There are also cases where the date code included alpha characters such as 0474A or Jan-74. Typically, the circuit breaker date code is specified in the component specification or drawing.

4.2.4.2 Assumptions.

None

4.2.4.3 Conclusions.

Based on the results and assumptions for date code variability, it can be concluded that, at the time the breakers were originally installed, there was no aircraft standard that recommended a specific date code format.

4.2.4.4 Recommendations.

Based on the results, assumptions and conclusions for date code variability, the following is recommended.

a. ARP 1199 should be revised to include a reference to EIA-476-B, "Date Code Marking." EIA-476-B specifies a four digit code, the first two digits are the calendar week and the second two digits are the calendar year that the component was produced.

b. Request SAE AE-8 to institute the EIA-476-B date code concept into all future circuit breaker specifications.

4.3 DISCUSSIONS OF PROCESS 1 TEST RESULTS.

The results of Process 1 testing are provided in appendices B and F. Radiographs of the breakers are provided in appendix E. Only 4 of the 60 breakers failed the Process 1 protocol tests.

4.3.1 Open Breaker Test Results.

4.3.1.1 Discussions.

The circuit breaker, HD213, was the only failed breaker that began the test in an open position. HD213 continued to pop open during routine preparation for the LVCR tests. It was considered a failure at that point and returned to the manufacturer for failure analysis (see appendix F). The results of the analysis indicated excessive wear of the latching mechanism that may be caused by excessive on and off cycling of the breaker. The breaker case was cracked at one of the bushings. The design requirement of the HD213 breaker includes 5,000 on and off cycles with an inductive load, and 10,000 cycles with no load without failure. HD213 was designated on the panel as WINDOW HEAT/RIGHT NO. 2/AC CONTROL. Similarly, circuit breakers HD181, HD182, and HD185 were respectfully designated on the panel as WINDOW HEAT/RIGHT NO. 2 DC CONTROL, WINDOW HEAT/RIGHT NO. 1, and WINDOW HEAT/RIGHT-5. HD181, HD182, and HD185 circuit breakers passed all the process 2 tests.

4.3.1.2 Assumptions.

The assumption concerning the HD213 mechanical failure is that circuit breakers with similar circuit designations would have been subjected to a similar number of on and off cycles during service life.

4.3.1.3 Conclusions.

Based on the results and assumption for the HD213 circuit breaker failure, it can be concluded that HD213 was a premature mechanical failure possibly caused by mechanical damage. If the assumption is invalid, an alternate possible conclusion is that the breaker is being used as a switch.

4.3.1.4 Recommendations.

Based on the results, assumption, and conclusions, instructions should be provided to maintenance personnel on the Boeing 727-232 aircraft to review the procedures incorporating circuit breaker designated WINDOW HEAT/RIGHT NO. 2/AC CONTROL on panel serial number 65-55630-2. If the breaker is being routinely cycled on and off, schedule a breaker replacement based on the design requirements of the breaker.

4.3.2 Lower and Higher Current Overload Results.

4.3.2.1 Discussions.

4.3.2.1.1 Lower Current Overload.

Three breakers failed the lower overload test at 200% rated current. Two of the breakers, EE191 and GE200, had borderline failures. The results indicated that both breakers opened slightly quicker than the required performance time. The two breakers also failed the lower current overload test after five on and off cycles.

EE191 and GE200 were returned to the manufacturer for failure analysis (see appendix F). The manufacturer found both breakers would pass the 200% overload when performed in accordance with MIL-C-5809 (still air, 25°C environment). Although not required, these breakers also pass the minimum and maximum limit of ultimate trip tests when performed by the manufacturer.

The third breaker, EE312, opened immediately at the 200% current overload. EE312 also failed after five on and off cycles. EE312 was returned to the manufacturer for failure analysis. The manufacturer noted that EE312 passed the 200% overload when performed in accordance with MIL-C-5809, but had slight increases in voltage drop at rated current.

4.3.2.1.2 Higher Current Overload.

All remaining breakers that passed the lower overload test also passed the higher overload test at 500% when required. For certain types of breakers, the higher current overload test was not performed because it was not specified as a requirement. Since there were no higher current overload failures, test block 14 was not performed.

4.3.2.2 Assumptions.

The following assumption is made for the lower and higher current overload results.

- All of the Process 1 tested breakers will provide similar results as noted in Process 2 testing.

4.3.2.3 Conclusions.

Based on the lower and higher current overload results and assumptions, it can be concluded that the breakers in aging aircraft continue to protect the wire from current overload when

periodically cycled on and off with no load. The breakers may cause some nuisance trips. See Process 2 discussions (section 4.4) for overload requirements for further validation of this conclusion, as well as recommendations based on these conclusions.

4.4 DISCUSSIONS OF PROCESS 2 TEST RESULTS.

The results of Process 2 testing (see appendix D) are provided in appendices B and I. Radiographs of the breakers are provided in appendix E. For ease of discussion, the Process 2 results are grouped together by the type of test performed.

4.4.1 Dielectric Withstand Voltage Test Results.

All tested circuit breakers passed the various dielectric withstand voltage tests. Therefore, Process 2 test blocks 5 through 9, 12 through 16, 32 through 36, 37 through 41, 42, and 43 were not performed (see appendix D). Although the leakage current for the dielectric voltage test was not required, it was recorded for information.

4.4.2 Insulation Resistance Test Results.

All tested circuit breakers passed the insulation resistance test (see blocks 17 and 29 of appendix D).

4.4.3 Operating Force Test Results.

All tested circuit breakers passed the button pullout and reset force requirements (see blocks 18, 24, 30, 54a, 58a, and 63 of appendix D).

4.4.4 Voltage Drops at Rated Current Test Results.

Although several breaker types have no voltage drop requirement at rated current (see appendix C), all the breakers were tested as specified in block 43a of appendix D. Those breakers that failed a specific voltage drop requirement were submitted to test block 43c for failure analysis, otherwise the breakers were submitted to the next test block in the protocol. Because there were only a few three-phase breaker specimens, only 1 three-phase breaker was submitted for failure analysis. The results of the voltage drop at rated current before and after opening and closing the breakers five times (blocks 43a and 43c respectively) are summarized in table 5.

4.4.4.1 Voltage Drop Comparison.

Counting the three-phase breakers as three separate breakers, the results indicated that 45 out of 240 breakers failed voltage drop at rated current, showing a 19% failure rate. When cycled on and off five times, seven out of the ten breaker types had decreased voltage drops at rated current, the improvement ranging from 3 to 193 percent. Breaker type A-5 showed no change, and breaker type B-10 experienced a 3 percent increase in voltage drop. There was no data for the tenth breaker type (D-7.5). Seven out of 31 breakers tested to block 43c passed the voltage drop requirement after being cycled on and off five times. Based on the averages after five on

and off cycles, the voltage drop at rated current was only 3 to 11 percent over specification requirements for five of the breaker types and was passing for the other four breaker types.

TABLE 5. VOLTAGE DROP COMPARISONS

Measured Voltage Drop at Rated Current in Volts (Initial in Block 43a)					Measured Voltage Drop at Rated Current in Volts (After Five Open and Close Cycles in Block 43c)					Notes
Breaker Type	Reqd. V Max	Number of Failures	Voltage Range (Min–Max)	Initial Average Voltage	Number of Failures	Voltage Range (Min/Max)	Average Voltage After Cycling	Percent Improve-ment	Average % Over Reqt.	
A-10	0.15	10	0.16-0.20	0.175	10	0.124-0.230	0.169	3%	7.5%	1
A-3	0.33	3	0.34-0.36	0.347	2	0.283-0.355	0.324	7%	(1.8)%	
A-5	0.25	4	0.26-0.26	0.26	3	0.249-0.271	0.260	0%	4%	
B-10	0.15	5	0.16-0.17	0.164	4	0.146-0.179	0.167	(2)%	11%	2
B-3	0.33	2	0.34-0.36	0.35	2	0.339-0.340	0.34	3%	3%	
B-5	0.25	3	0.26-0.37	0.30	3	0.266-0.270	0.268	12%	7%	3
C-3	0.55	1	0.66	0.66	0	0.225	0.225	193%	(59)%	
D-7.5	0.30	14	0.31-0.34	0.315	-	-	-	-	-	4
E-8	0.30	2	0.31-0.81	0.56	0	0.179-0.268	0.224	150%	(25)%	5
J-3	0.79	1	0.97	0.97	0	0.772	0.772	25%	(2)%	

1. DH149 tripped during test (value not recorded).
2. JH251 tripped during test (value not recorded).
3. IE238 had very high LVCR values (voltage drop at rated current not recorded)
4. D-7.5 represents 5 three-phase tandem breakers (15 single phase breakers). One single-phase breaker passed. One breaker at 0.61 volt was considered as an anomaly and not included in the average.
5. Three-phase tandem breaker, LG291, with one phase passing.

4.4.4.2 Voltage Drop Design Criteria.

The limited data obtained from the design information survey (see appendix A) indicates a typical aircraft critical circuit is designed to have a required maximum voltage drop at rated current of up to:

a. 2 volts direct current (Vdc) for 28 Vdc electrical power,
b. 4 volts alternating current (Vac) for 115 Vac electrical power, and
c. 7 Vac for 200 Vac electrical power.

A comparison of the differences between the design maximum electrical power voltage drop at rated current and the maximum increase in voltage drop measured after five on and off cycles for each circuit breaker type is provided in table 6. Only the five circuit breaker types that failed the average voltage drop requirement after five on and off cycles are listed.

The results of table 6 indicate that the increase in measured voltage drop at rated current will only cause a maximum of 4%, 2%, and 1.1% increase respectively in circuit voltage drop for 28 Vdc, 115 Vac, and 200 Vac electrical systems. These higher values seem to be related only to the A-10 breaker type. The more typical range of circuit voltage drop increase is 1% or less.

TABLE 6. VOLTAGE DROP DESIGN COMPARISONS AFTER ON AND OFF CYCLES

Breaker Requirement		Voltage Drop/Current Measured Values		Difference (Requirement–Measured)	Percent of Voltage Design Maximum allowable		
Type	Voltage Drop (V)	Voltage Range (V)	Maximum Voltage (V)	(V)	28 Vdc (2 V)	115 Vac (4 V)	200 Vac (7V)
A-10	0.150	0.124-0.230	0.230	0.080	4.0%	2.0%	1.1%
A-5	0.250	0.260-0.260	0.260	0.010	0.5%	0.25%	0.14%
B-10	0.150	0.146-0.179	0.179	0.029	1.5%	0.73%	0.41%
B-3	0.330	0.339-0.340	0.340	0.010	0.5%	0.25%	0.14%
B-5	0.250	0.266-0.270	0.270	0.020	1.0%	0.5%	0.29%

Based on the results and discussion for the voltage drops at rated current, the following is assumed.

a. The breaker, after one on and off cycle, will typically provide the same voltage drop results as five on and off cycles (see LVCR discussions for further details).

b. The circuit voltage drops in table 6 typically represent most commercial aircraft design requirements.

c. Circuit breakers that have very high voltage drops at rated current after cycling would typically be expected to generate heat that will cause a non-temperature-compensated thermal circuit breaker to trip at a lower current. A temperature-compensated thermal circuit breaker may be less sensitive to this type of temperature rise. This assumes that the heat from the contacts will be transferred roughly equivalently to the heat sensitive strips and the compensating member. A non-temperature-compensated thermal circuit breaker strip would detect the increased heat as an artificial increase in current. A temperature-compensated thermal circuit breaker would detect the heat as increased environmental temperature, rather than an artificial increase in current. In other words, depending on how the breakers are calibrated and designed, a non-temperature-compensated thermal circuit breaker would typically be expected to open sooner than a temperature-compensated breaker when resistive heating occurs.

d. All electrical circuits are designed to permit small rises in voltage drop at rated current.

e. Cycling breakers periodically will not generally cause the breaker to reach the trip cycle design limit during its service life.

4.4.4.3 Conclusion.

Based on the results and assumptions for the voltage drops at rated current test, the following is concluded.

a. Cycling the breaker on and off improves the voltage drop at rated current.

b. Small rises in voltage drop (1% to 4%) at rated current in aging aircraft does not have a significant impact on the electrical system.

4.4.4.4 Recommendation.

Based on the results, assumptions, and conclusions for the voltage drop at rated current test, it is recommended the breakers not be replaced but periodically cycled on and off.

4.4.5 Minimum and Maximum Limit of Ultimate Trip Test Results.

4.4.5.1 Minimum Limit.

Thirty-nine circuit breakers out of 204 tested failed the minimum limit of ultimate trip, but all circuit breakers tested passed the 90% minimum of ultimate trip.

4.4.5.2 Maximum Limit.

Twelve circuit breakers out of 206 breakers tested failed the initial maximum limit of ultimate trip. Only one breaker failed the ±10% endurance limit of ultimate trip.

4.4.5.3 110% Maximum Failure Limit.

Only one circuit breaker, (DA112) failed after the 110% maximum limit of ultimate trip was submitted to five on and off cycles then retested. DA112 still failed the 110% requirement. DA112 was then submitted to the manufacturer for failure analysis. DA112 passed the manufacturer's test, but it was noted that the button-cam extension spring was no longer attached to the spring insulator. The manufacturer indicated that the disconnected spring did not affect the result. The failure is considered an anomaly. For this reason, it was not included as part of the minimum and maximum limit of ultimate trip analysis.

4.4.5.4 Design Requirements (Initial Limits).

As discussed in section 4, the minimum and maximum limit of ultimate trip requirements are designed to prevent breaker trips caused by slight increases in load current on the wire. The range of minimum limit of ultimate trip required for the tested breakers to remain closed for at least 1 hour is 5% (denoted as the 105% minimum trip test) to 15% (denoted as the 115% minimum trip test) of the breaker's rated current. The range of maximum limit of ultimate trip required for the tested breakers to open within 1 hour is 38% (denoted as the 138% maximum trip test) to 45% (denoted as the 145% maximum trip test) of the breaker's rated current. These percentages vary with the breaker type. Since the wire is designed to perform for the life of the

aircraft (see SAE specification AS 50881), the electrical system designer had to choose a wire size for the tested breakers that minimized the wire aging caused by a possible continuous 5% to 15% increase in load current over the rated current. The designer had to also choose a wire size that minimizes the effects of multiple occurrences of an increased current load for 1 hour of at least 38% to 45% above the tested circuit breaker's current rating.

4.4.5.5 Design Requirements (Aging Endurance Limits).

In addition to the initial limited increases in load currents, the tested breakers are also designed to permit the minimum and maximum limits of ultimate trip to change by an additional ±10% as the breakers age (see MIL-C-5089). The ±10% change permits the minimum limit of ultimate trip to be 90% of the initial minimum required value and the maximum limit of ultimate trip to be 110% of the initial maximum required value. The ±10% change is permitted after the breaker has been aged by on and off cycles. The on and off cycle requirements for most thermal breakers are 5,000 cycles with a resistive load, 2,500 cycles with an inductive load, or 10,000 cycles with no load (see MIL-C-5809). The test protocol presumes the tested breakers have been aged to less than this ±10% endurance requirement, and therefore, the on and off cycles were not performed as part of the protocol. The change in breaker calibration due to aging had to be considered by the electrical system designer to avoid trips caused by current load increases because of the aging equipment and circuit breaker. Since the tested breakers (depending on the type) permit an initial 38% to 45% increase in rated current then another 10% increase as the breaker ages, the designer had to choose a wire size that carried the load currents 41.8% (110% of 38%) to 49.5% (110% of 45%) above the breaker's rated current. The results obtained from an aircraft manufacturer indicate the electrical designer typically choose a wire size that carried a current load 100% greater than that expected to be required by the equipment load. The 41.8% value is well below the conservative 100% margin designed for the wire.

4.4.5.6 Assumptions.

Based on the results and discussion of the minimum and maximum limit of ultimate trip the following statements are assumed.

a. The wire is designed for the life of the aircraft.

b. The breakers were designed for a ±10% change in ultimate trip requirements as the breakers age.

c. The electrical system is designed for a conservative, maximum wire current load of at least 50% of the wire current rating.

4.4.5.7 Conclusion.

Based on the results and assumptions for the minimum and maximum limit of ultimate trip test, the following is concluded.

- The circuit breakers in aging aircraft have not exceeded their design limits for protecting the wire from slight increased current levels caused by aging of the electrical distribution system.

4.4.5.8 Recommendation.

Based on the results, assumptions, and conclusion for minimum and maximum ultimate trip tests, it is recommended the breakers not be replaced.

4.4.6 Lower Current Overload Test Results (150% and 200%).

The 200% lower current overload test was performed on all circuit breaker families except the family designated as manufacturer code L-0.5 (see appendix C). The L-0.5 family of circuit breakers only has a 150% lower current overload requirement.

4.4.6.1 Lower Current Overload, 200% Results.

Eleven out of 182 circuit breakers failed the 200% lower current overload test specified in block 55 for a failure rate of 6%. This failure rate correlates with the 5% failure rate (3 out of 60 breakers) noted for the 200% lower overload performed on the first 60 breakers in Process 1. Seven of the 14 combined Process 1 and Process 2 breakers tripped below the minimum trip time and seven tripped above the required maximum trip time. After subjecting the 11 Process 2 failures to five on and off cycles, seven of the breakers passed the lower current overload requirement. The five remaining failures all exceeded the maximum trip time required to open the breaker. All breakers were submitted to the manufacturer for failure analysis (see appendix F). Only one breaker passed when tested by the manufacturer in accordance with MIL-C-5809. The failing breaker, GE174, tripped 0.3 seconds earlier than the required 15 seconds minimum tripped time.

4.4.6.1.1 Assumptions.

The wire size is conservatively rated at 50% of the required load current.

4.4.6.1.2 Conclusion.

Based on the results and assumption for the 200% current overload test, the following may be concluded.

a. Cycling the breaker on and off improves the breaker's 200% lower current overload characteristics.

b. The circuit breakers in aging aircraft have not exceeded their design limits for protecting the wire from current surges or shorts caused by aging of the electrical load or the distribution system.

c. The unlikely, worst-case scenario for some breakers is a nuisance trip caused by load current surges. Maintenance personnel will replace nuisance trip breakers.

4.4.6.1.3 Recommendations.

Based on the results, assumptions, and conclusions for 200% current overload tested breakers, it is recommended the breakers not be replaced but periodically cycled on and off.

4.4.6.2 Lower Current Overload, 150% Results.

Fourteen out of 23 circuit breakers failed the 150% lower current overload for the L-0.5 family of circuit breakers for a failure rate of 64%. The L-0.5 breaker type is a 0.5-amp-rated breaker and has no higher current overload requirement. The smaller the amp rating for a breaker the more sensitive the breaker becomes to slight changes in test currents. The L-0.5 breaker is required to open between 1 and 8 seconds at a 150% current overload. Thirteen out of 14 failed breakers open in less than 1 second (0.6 to 0.9 second). The remaining breaker exceeded the 8-second maximum requirement. After five on and off cycles, the breaker that exceeded the 8-second requirement passed the 150% overload test. Twelve out of the remaining 13 breakers still had values below the 1-second requirement. The thirteenth breaker had a borderline passing value of 1.1 seconds (0.1 second above the minimum requirement). The manufacturer performed the 150% test three times on the 14 failing breakers. Four breakers failed the first two times and five the last time. Different breakers passed or failed each time the test was performed. In all cases, the breakers tripped before the minimum 1-second requirement.

4.4.6.2.1 Assumption.

The breakers are replaced, if nuisance trips occur.

4.4.6.2.2 Conclusions.

Based on the results and assumptions for the L-0.5 breaker types, the following may be concluded.

a. The high failure rate of 61% indicated L-0.5-amp breakers are not used in circuits that generate current surges exceeding 150% of current rating, otherwise these would be nuisance trip breakers that would have been replaced by maintenance requirements.

b. Cycling the breaker on and off may improve the breaker's 150% lower current overload trip characteristics.

c. The circuit breakers in aging aircraft have not exceeded their design limits for protecting the wire from current surges or shorts caused by aging or failure of the electrical load.

4.4.6.2.3 Recommendation.

Based on the results, assumptions, and conclusions for 150% current overload tested L-0.5 breakers, it is recommended the breakers not be replaced but periodically cycled on and off.

4.4.7 Higher Current Overload Test Results (400%, 500%, and 600%).

4.4.7.1 Single-Phase Breakers.

As reported in section 4.2.2, there were no failures as a result of the 400%, 500%, and 600% higher-current overload tests performed on the breakers in Process 1. For the Process 2 tests, 5 out of 168 breakers failed for a failure rate of 3%. The percentage of current overload used for a particular breaker type was determined by the circuit breaker requirement provided in appendix C. The high-current calibration curve requires the breaker to stay closed for a very short period of time (minimum time) and then open within a maximum period of time. Three of the five breakers tripped before the required minimum time, and two breakers tripped after the required maximum time. After five on and off cycles, two breakers out of five passed the overcurrent requirement. Of the three remaining breakers that failed, two failed the required minimum time, and one failed the required maximum time. When the failed breakers were tested by the manufacturer in accordance with MIL-C-5809, all the breakers passed the higher-current overload requirement. The circuit breaker failures by ampere rating are as follows.

Ampere Rating (amps)	Number of Failures
1	1 (500%)
8	1 (400%)
5	2 (600%)
10	1 (500%)

4.4.7.2 Three-Phase Breakers.

The three-phase breaker designated as LG291A, LG291B, and LG291C (see section 2.1) failed 500% current overload on phase A (LG291A). Phases B and C (LG291B and LG291C respectively) were not tested after failing the voltage drop at rated current. All the other three-phase circuit breakers were tested on all phases and passed all the tests, except the voltage drop at rated current test, as reported section 4.3.4. The low rate of failure for three-phase breakers indicates the presumption in the protocol deviation noted in section 3.2 is acceptable.

4.4.7.3 Assumptions.

None

4.4.7.4 Conclusions.

Based on the results and assumptions for the 400%, 500%, and 600% current overloads the following is concluded.

a. Cycling the breaker on and off improves the breaker's 400%, 500%, and 600% higher-current overload characteristics.

b. The circuit breakers in aging aircraft have not exceeded their design limits for protecting the wire from current surges or shorts caused by the aging of the electrical load or the distribution system.

4.4.7.5 Recommendation.

Based on the results, assumptions, and conclusions for 400%, 500%, and 600% current overload, it is recommended the breakers not be replaced but periodically cycled on and off.

4.4.8 Low Voltage Contact Resistance Test Results.

The low voltage contact resistance (LVCR) test is designed to monitor the changing resistance of the circuit breaker's mated contacts as the contacts are exercised on and off (refreshed) by mechanical wiping or electrical wiping. Circuit breakers either have one or two mated contact pairs. For each breaker tested, the average of 10 LVCR readings was recorded after each major test event in both protocols. The LVCR was also monitored as a part of the failure analysis (FA). For each FA, a single LVCR reading was recorded followed by an on and off cycle for a total of five cycles followed by a final LVCR reading. These results are recorded and summarized in appendix F. The data is condensed as shown in table 7.

TABLE 7. LOW VOLTAGE CONTACT RESISTANCE COMPARISONS

	LVCR Averaged by Breaker Type (millivolts)							
Breaker Type	Initial	After 2 Cycles	After Min. Trip	After Max. Trip	After 150%/200% Trip	After 500% Trip	After 5 FA Cycles	Note
A-10	18	26	5	18	5	3	54	1
A-3	23	77	55	78	53	38	130	
A-5	44	48	23	27	24	21	102	
B-1	262	266	233	268	234	196	271	
B-10	16	43	19	28	16	5	380	
L-0.5	466	468	461	461	461	N/A	461	2

1. Sampling size dropped from 17 to 5 specimens (after 2 cycles).
2. Breaker only has a 150% overload current requirement. Sampling size dropped from 23 to 9 specimens (after max. trip).

A review of the average LVRC results for the breaker types shown in table 7 indicated the LVCR value in relative terms changes very little after on and off cycles with or without loads. The increased values (after 5 FA cycles in table 7) indicate breakers that failed a specific performance requirement did have slightly higher LVCR values, but there is insufficient data to establish this increase as a trend.

4.4.8.1 Assumptions.

None

4.4.8.2 Conclusions.

Based on the results and assumptions for the LVCR, it can be concluded that the conditions of the contacts have little or no affect on the circuit breaker performance.

4.4.8.3 Recommendations.

None

4.4.9 Temperature Rise Test Results.

The temperature rise was monitored during all calibration tests. A general review of the data indicated that temperature rise typically increases with the current rating of the breaker. A temperature rise is expected, since more current generates more heat; however, there were exceptions to this proportionality. There appeared to be little or no relationship between the temperature rise and a particular failure mode.

4.4.9.1 Assumptions.

None

4.4.9.2 Conclusions.

There is insufficient data to indicate a relationship between temperature rise and circuit breaker test characteristics.

4.4.9.3 Recommendations.

None

4.4.10 Date Code Test Result Comparisons.

Table 8 was developed to try to determine if there is a relationship between the age of a circuit breaker and its failure rate. The combined date codes of all the breakers tested indicated the breakers varied in age from 1968 to 1996. The numerous breaker types in the test program contains a variety of manufacturing dates, but those provided in table 8 were chosen because the breaker types had a significant number of specimens and the date codes covered a broad period of time. The results indicated a 47% failure rate occurred for the L-0.5 breaker for date codes 1972 to 1993. The L-0.5 breaker result is skewed by the fact that 41% of the failures are only in the 1974 date code. The B-3 breaker had a 14% failure rate for date codes 1969 to 1991. The B-10 breakers had a 13% failure rate for date codes 1973 to 1986. The results indicate that the failures do occur in the earlier date codes.

4.4.10.1 Assumptions.

The assumption for date code analysis is that, in general, all breakers types will change similarly over time in a benign environment.

4.4.10.2 Conclusions.

The conclusion based on the date code analysis results is that the oldest breakers have a tendency to deviate further from the original specification requirements than the newer ones.

TABLE 8. DATE CODE COMPARISONS

P1 and P2 Combined			Failures				
Breaker Type	Date Code	Number of Breakers	90% Minimum Trip	110% Maximum Trip	150% or 200% Overload	400%, 500%, or 600% Overload	Voltage Drop at Rated Current
L-0.5	1972	1					
	1974	22		1	10		
	1982	1					
	1988	1					
	1991	3			3		
	1992	1			1		
	1993	3					
B-3	1969	15*					2
	1973	2					
	1983	1					
	1987	1					
	1988	1					
	1989	1					
	1990	1					
	1991	1					
B-10	1973	22			1	1	3
	1974	7					
	1984	1					
	1985	4					
	1986	2					

*One Breaker would not stay closed.

5. SUMMARY OF PROCESS 1 AND PROCESS 2 CONCLUSIONS AND RECOMMENDATIONS.

5.1 CONCLUSION.

The results of the tests protocols indicate that circuit breakers installed in aircraft with extended service life will continue to protect the electrical wire provided the maintenance procedures recommended in sections 5.2 to 5.4 and in paragraph 5.8 of SAE ARP 1199 are performed at least once a year.

5.2 MAINTENANCE MANUAL RECOMMENDATION.

The results indicate that the aircraft maintenance manuals should be reviewed and updated to reflect the following actions:

a. Provide instruction to cycle all breakers off and on once a year.

b. Provide instruction on how to protect the back panels during routine maintenance actions.

c. Provide instruction on how to clean the back panels.

d. Provide instruction to examine all panels for loose, broken, misapplied circuit breaker wire termination hardware, and require replacement with the correct hardware.

e. Provide clear instructions on how to avoid cross-threading screws or thread-stripping breaker terminals and require complete replacement of the breaker when it occurs.

f. Provide instructions on how to inspect for overheating and electrical arcing as well as defines what repairs are needed to minimize hotspots and prevent future occurrences.

g. Provide instruction that clearly defines the circuit breaker's wire termination hardware, and permit no substitutions unless there is a process that provides clearly define alternatives until direct replacements can be performed.

h. Provide instructions to maintenance personnel to review all processes that may be using breakers as on and off devices. If a breaker is routinely cycled on and off, establish a breaker replacement schedule based on the design requirements of the breaker or redesign the circuit to include a switch.

5.3 SAE STANDARD RECOMMENDATIONS.

The results indicate that the SAE AE-8 Committee, "Aero Electrical/Electronic Distribution Systems," be requested to perform the following.

a. Revise ARP 1199, paragraph 5.8.1 b4, to recommend circuit breaker termination-securing parts be replaced with identical parts and permit no substitutions without a process for appropriate replacement at a scheduled maintenance period.

b. Revise ARP 1199 to include a reference to EIA-476-B, "Date Code Marking." EIA-476-B specifies a four-digit code, the first two digits are the calendar week and the second two digits are the calendar year in which the component was produced.

c. Revise ARP 1199 and ARP 4404 to include more definitive guidelines on when multiple circuits can be used with one circuit breaker.

d. Revise AS 50881 and AS 5809 to include when and how multiple wires in one lug or multiple lugs on one circuit breaker terminal can be applied.

5.4 FAA ADVISORY CIRCULARS.

It is recommended that the appropriate FAA Advisory Circulars refer to SAE ARP 1199, ARP 4404, and AS 50881 for Electrical Distribution System Guidance.

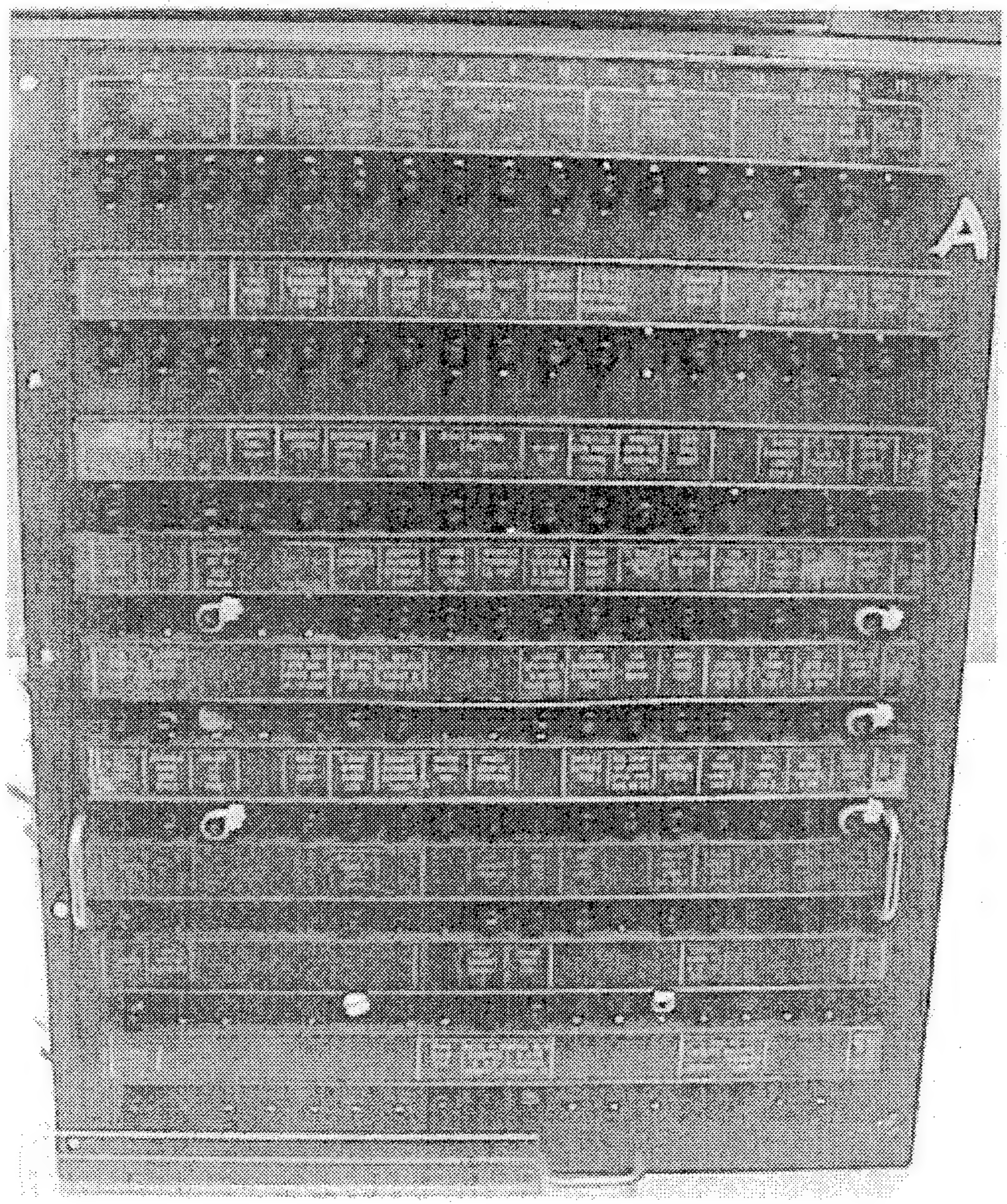
APPENDIX A—AIRCRAFT INFORMATION

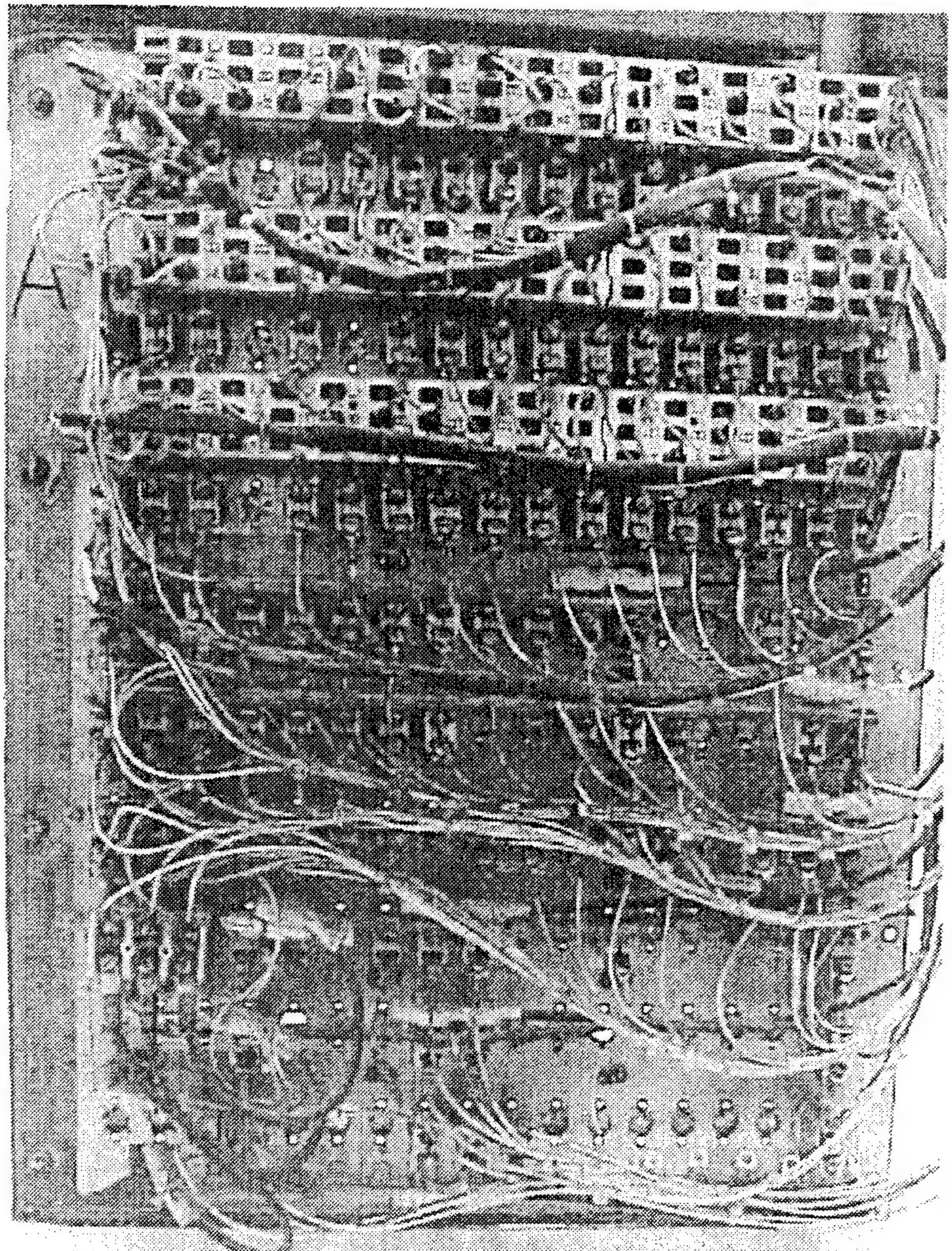
A.1 AIRCRAFT DEPLOYMENT HISTORY.

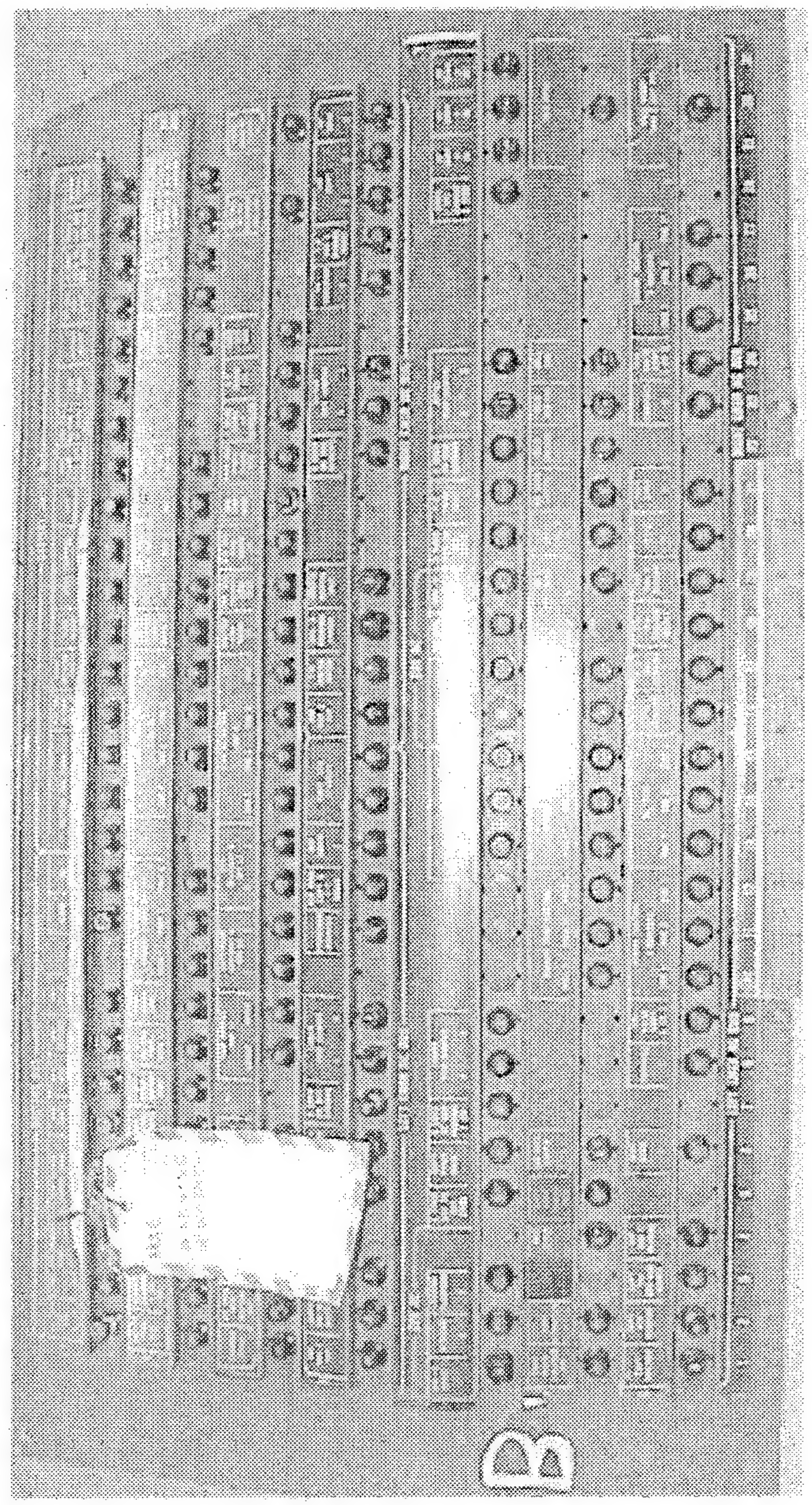
Process 1 And 2 Aircraft Information

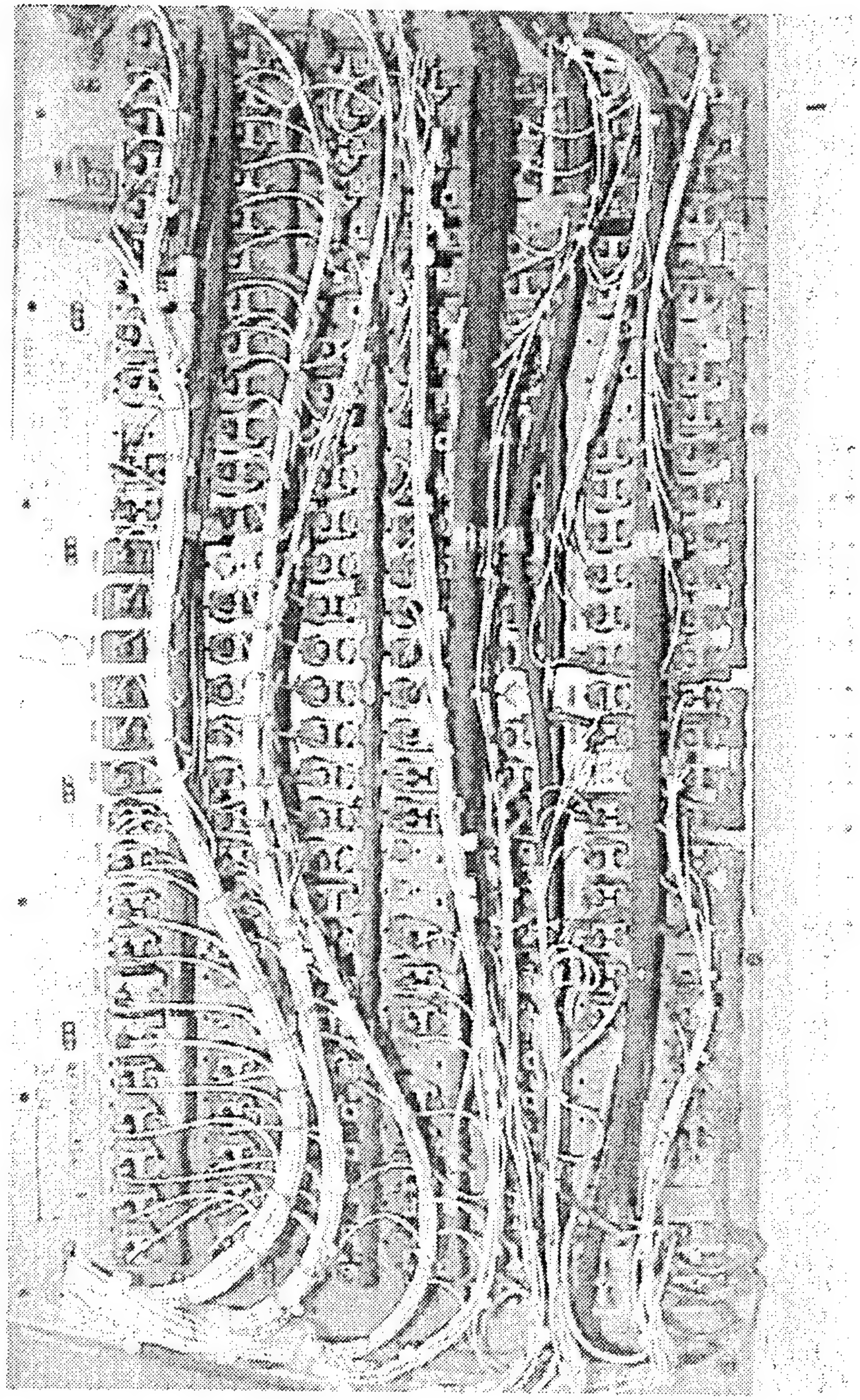
Boeing 727-232	McDonnell-Douglas DC-10
Serial No. 20756	Serial No. 46627
Mode S Code 51361325	
Reg. No. N479DA	Reg. No. N393FE
Line No. 1028	Line No. 205
Engine Type JT8D-15	Engine Type CF6-6D
Variant 200 Advanced (Stage 3 Huskits)	Variant 10F(M)
Minor Variant 232 ADV	Minor Variant 10F(M)
Owner: Aiborne Accessory Group Inc.	Owner: Federial Express
Roll-out Date 3/3/74	Roll-out Date 5/16/75
First Flight Date 4/3/74	First Flight 6/6/75
Cumulative Flight Hours 66224	Cumlative Flight Hours 73642
Cumulative Cycles 58831	Cumulative Cycles 25865
Status Permanently Witdrawn Date 10/12/99	Status Still Active
Panel Removed Date Approx 5/01	Panel Removed Date Approx 5/01
Panel Designation E (Serial No.65-55630-4)	Panel Designation A (Serial No. ABN707-3D, ABN7071-IF, ABN7071-1E)
Panel Designation F (Serial No. 65-55630-5)	Panel Designation B (Serial No. BPOOE-418, BN13-405, ABN7004-401)
Panel Designation G (Serial No. 65-65190-15)	Panel Designation C (Serial No. ABN7070-3U, BN12-412, ABN7050-1, BPOOD-402)
Panel Designation H (Serial No. 65-55630-2)	Panel Designation D (Serial No. ABN7069-1)
Panel Designation I (Serial No. 69-47119-1)	
Panel Designation J (Serial No. 65-65192-1)	
Panel Designation K (Serial No. 65-65191-6)	
Panel Designation L (Serial No. 65-55630-3)	
Aircraft History	Aircraft History
9/72: Delta Airlines / 200 advance / 232ADV	6/75: United Airlines / N182BU
11/93: Delta Airline / Stage 3 Huskits / 232ADV	4/86: Leased to World Airlines / N182BU
6/99: Untied Technologies Corp / Parked	11/99: Federial Express / N393FE / Parked For Mod
10/99: Airborne Accessory Group / Parked	
10/99: Republic Advance Frightner Inc / Parked	
10/99: Airborne Accessory Group / Parked	
10/99: Airborne Accessory Group / Withdrawn	

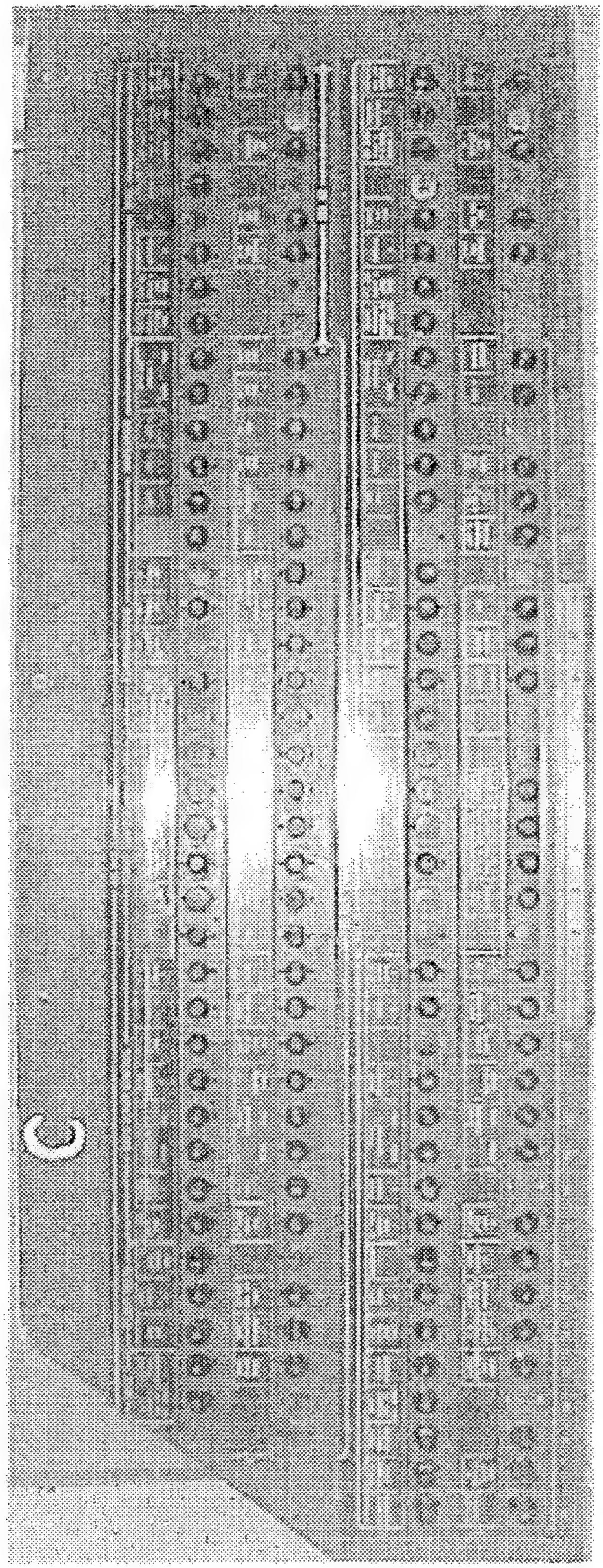
A.2 AIRCRAFT PANEL PHOTOGRAPHS.

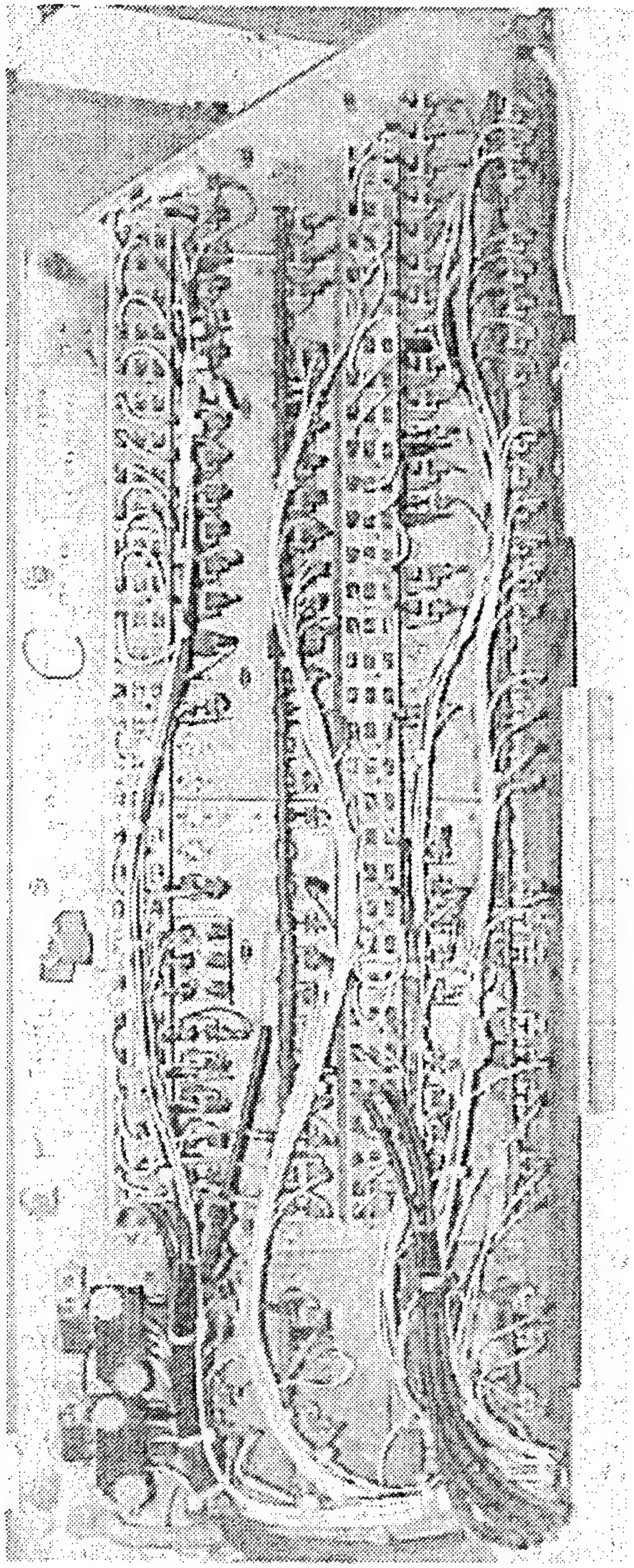


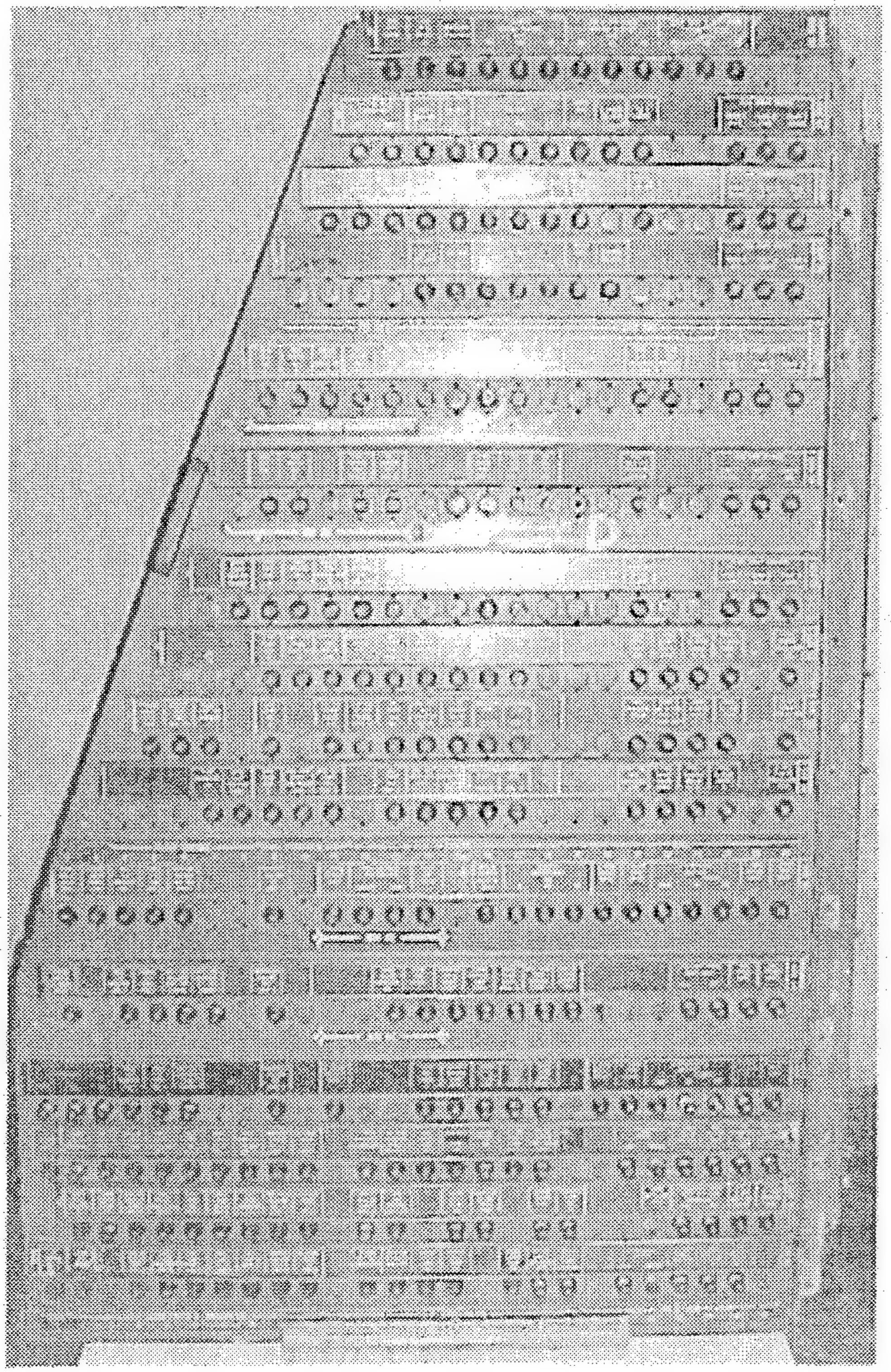


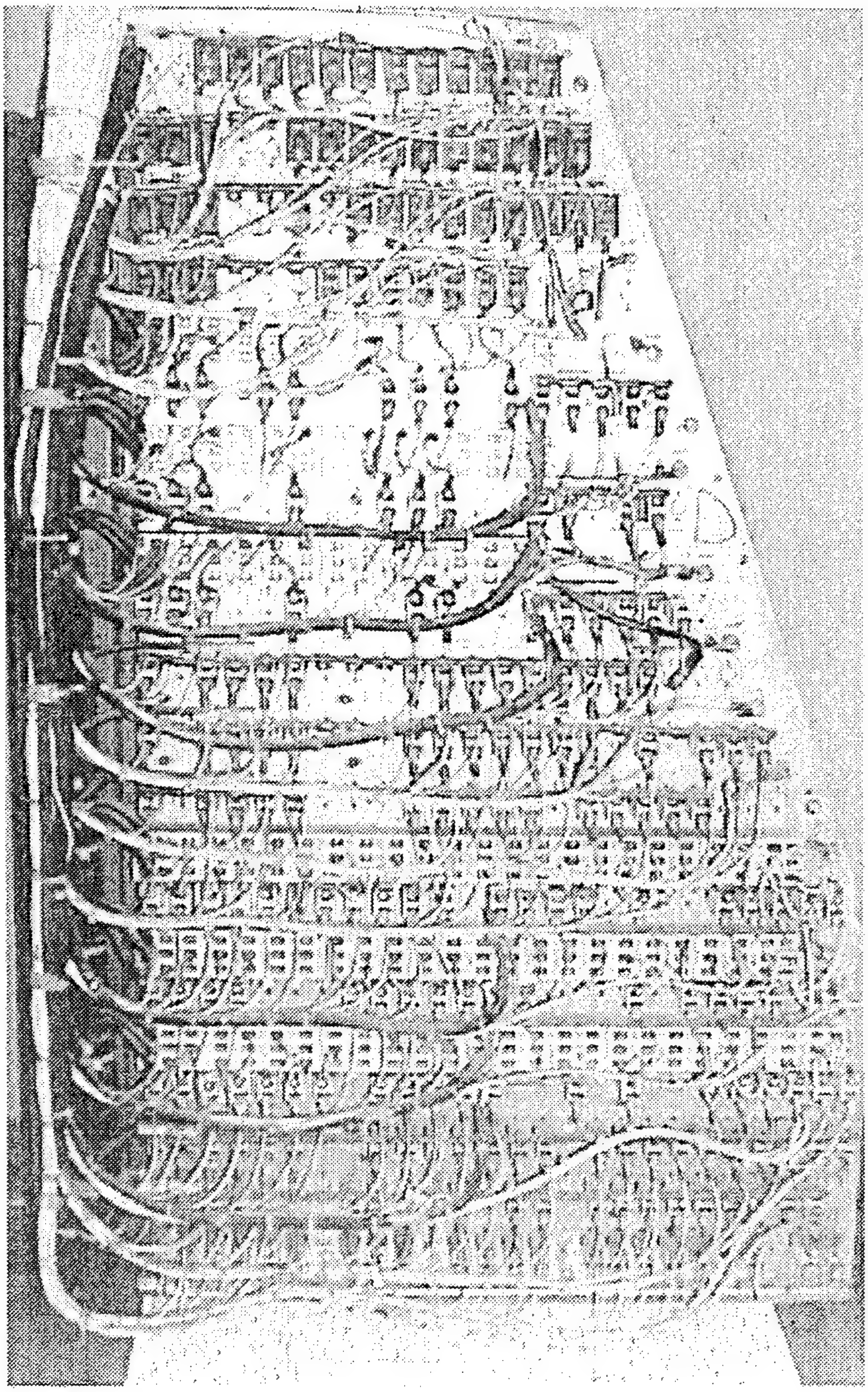


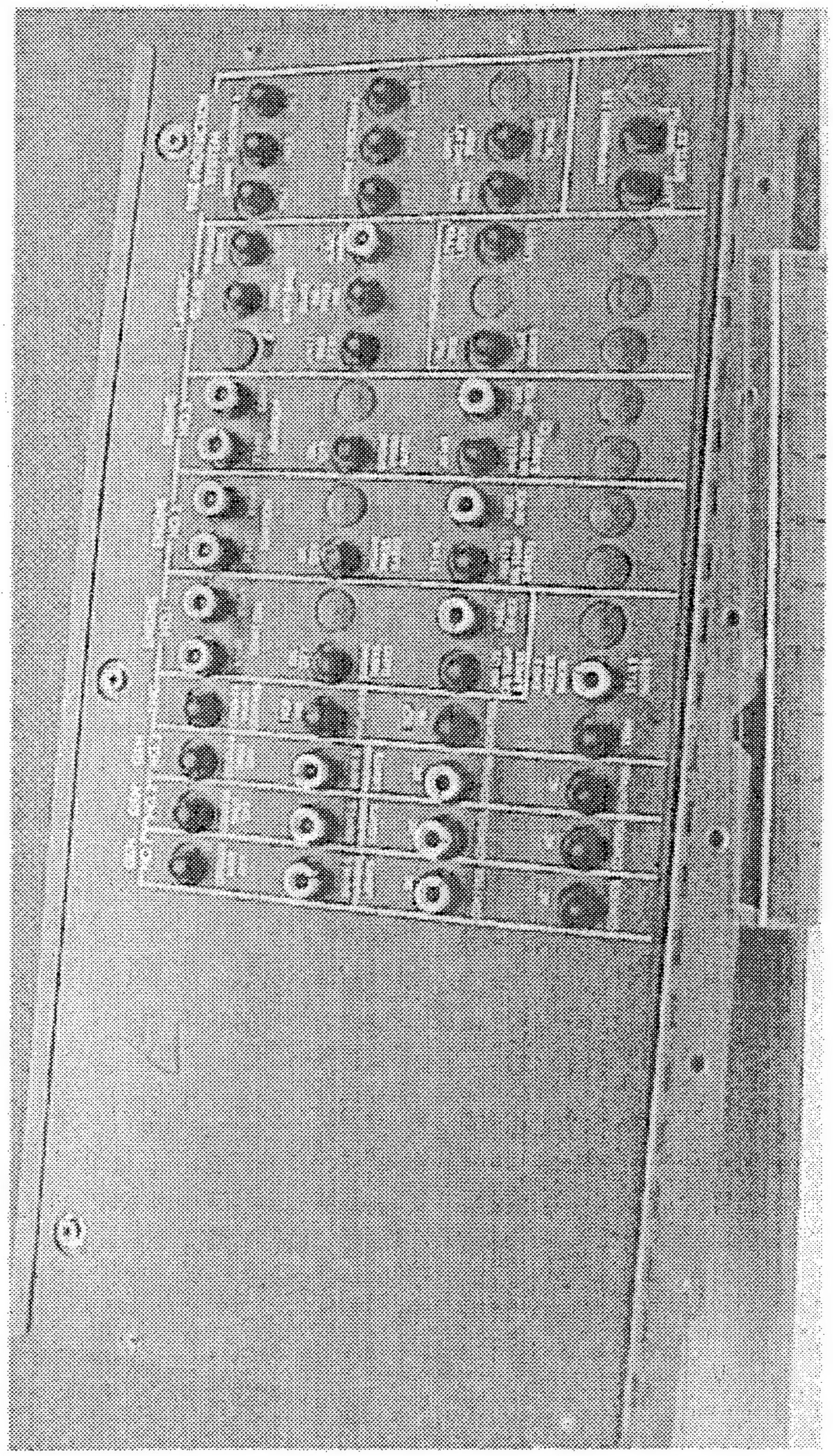


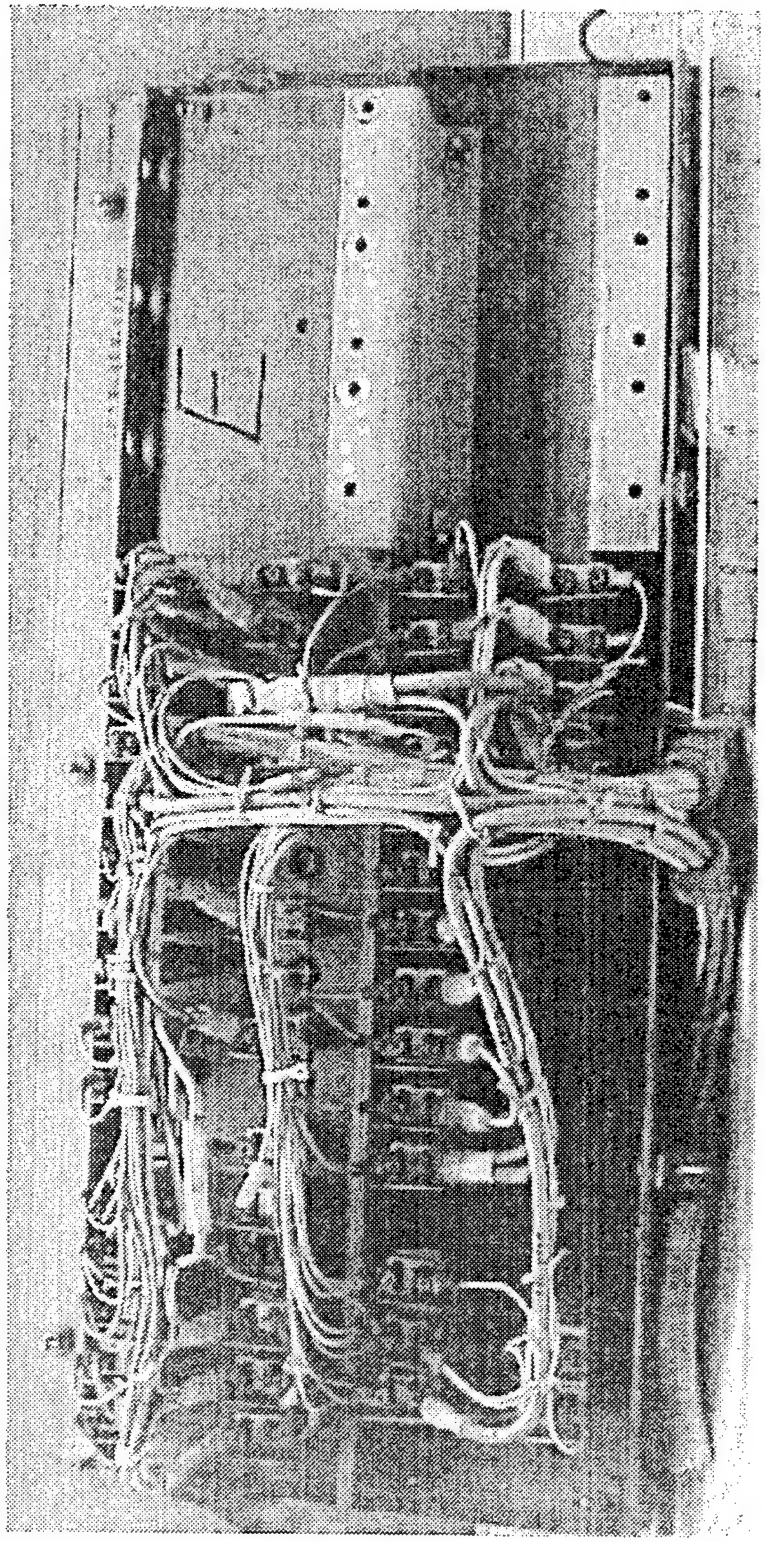


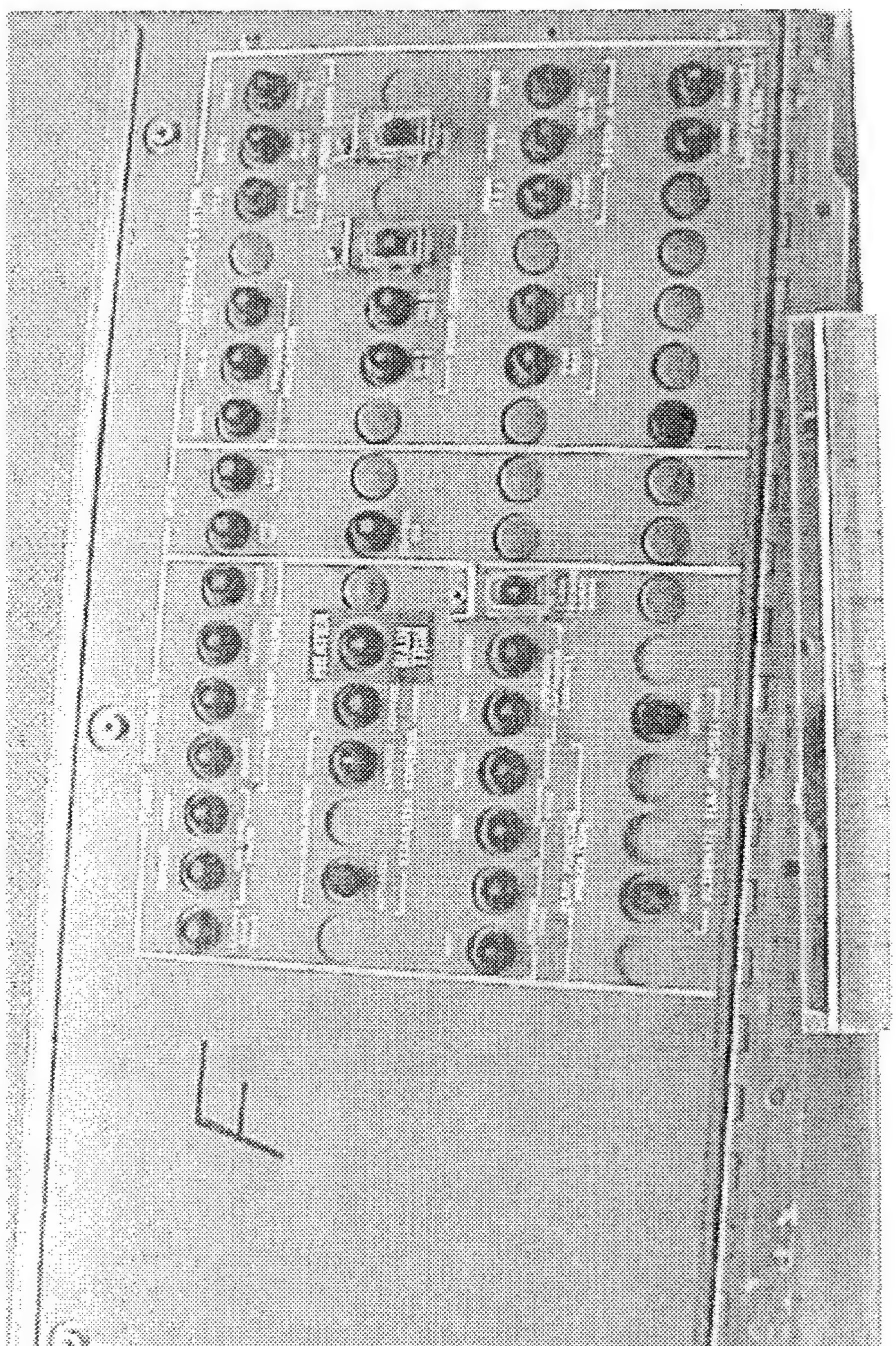


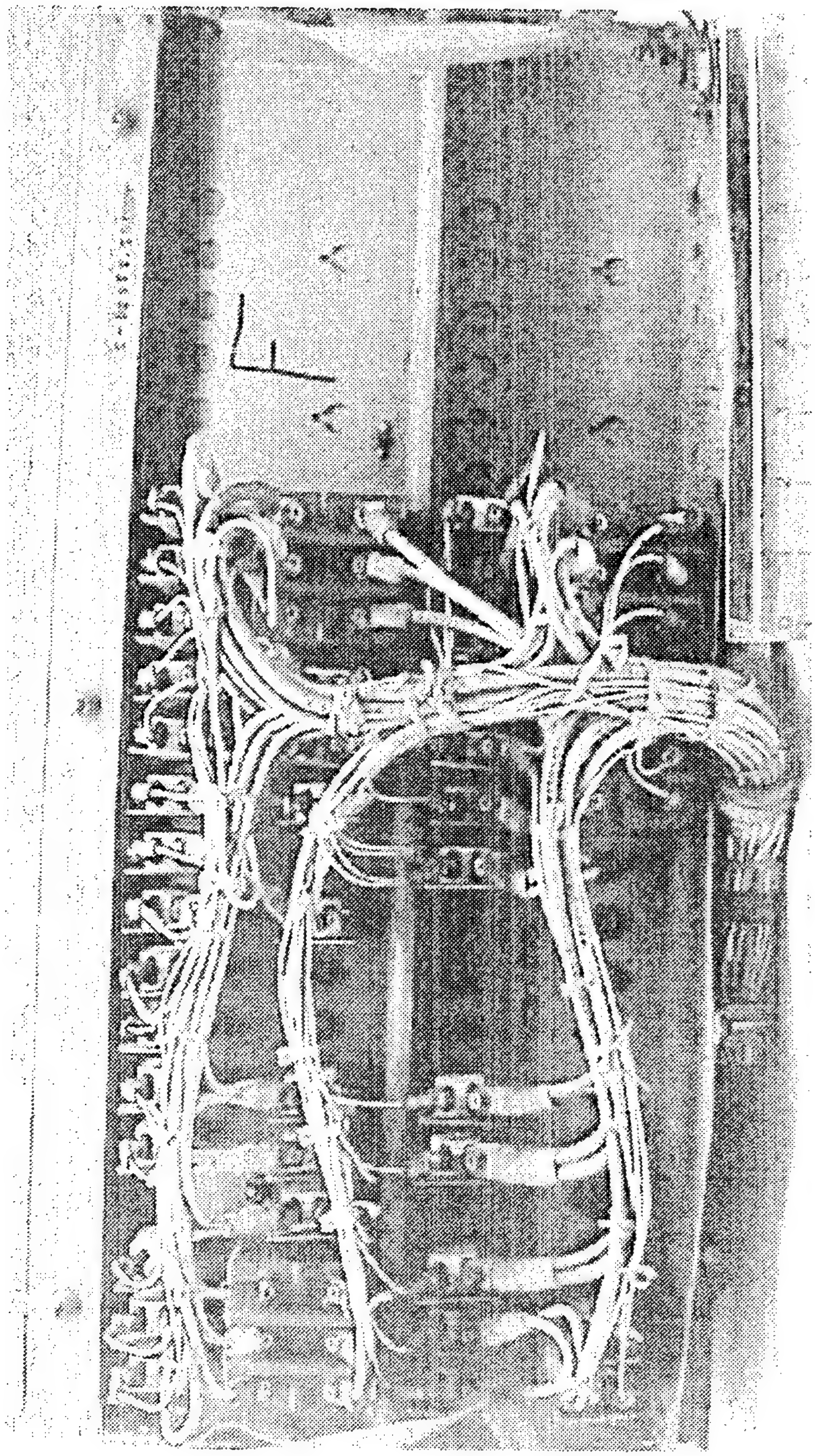


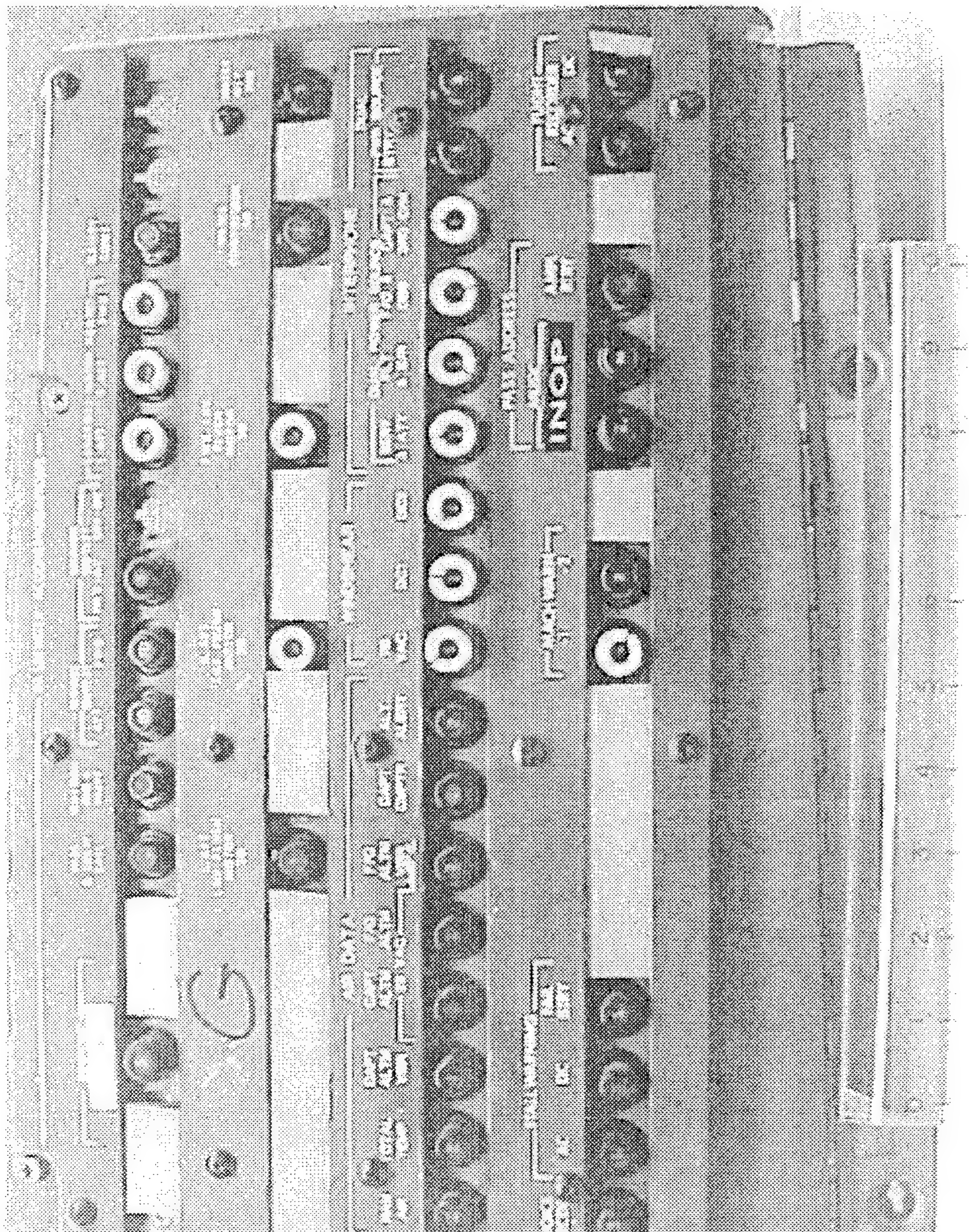








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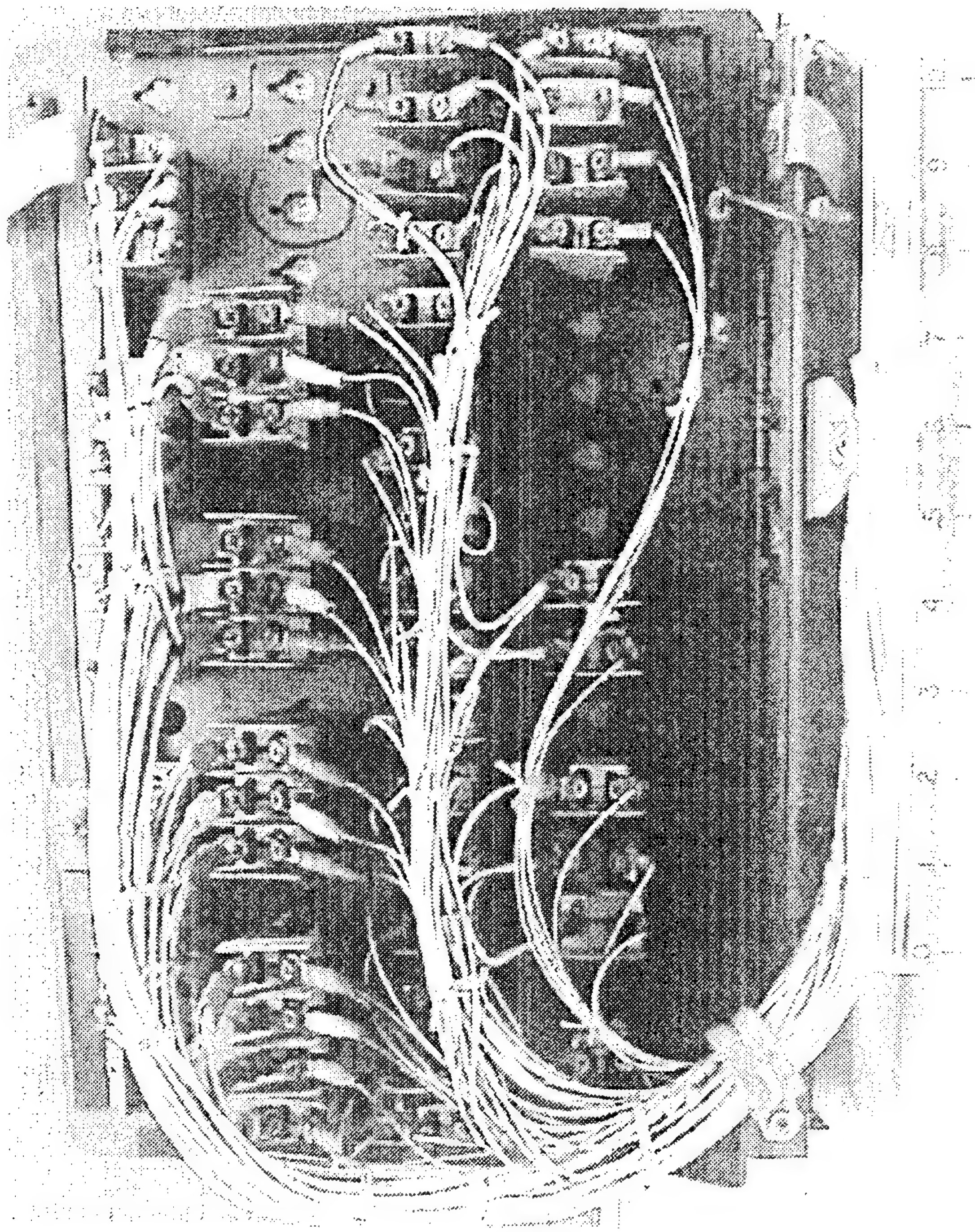
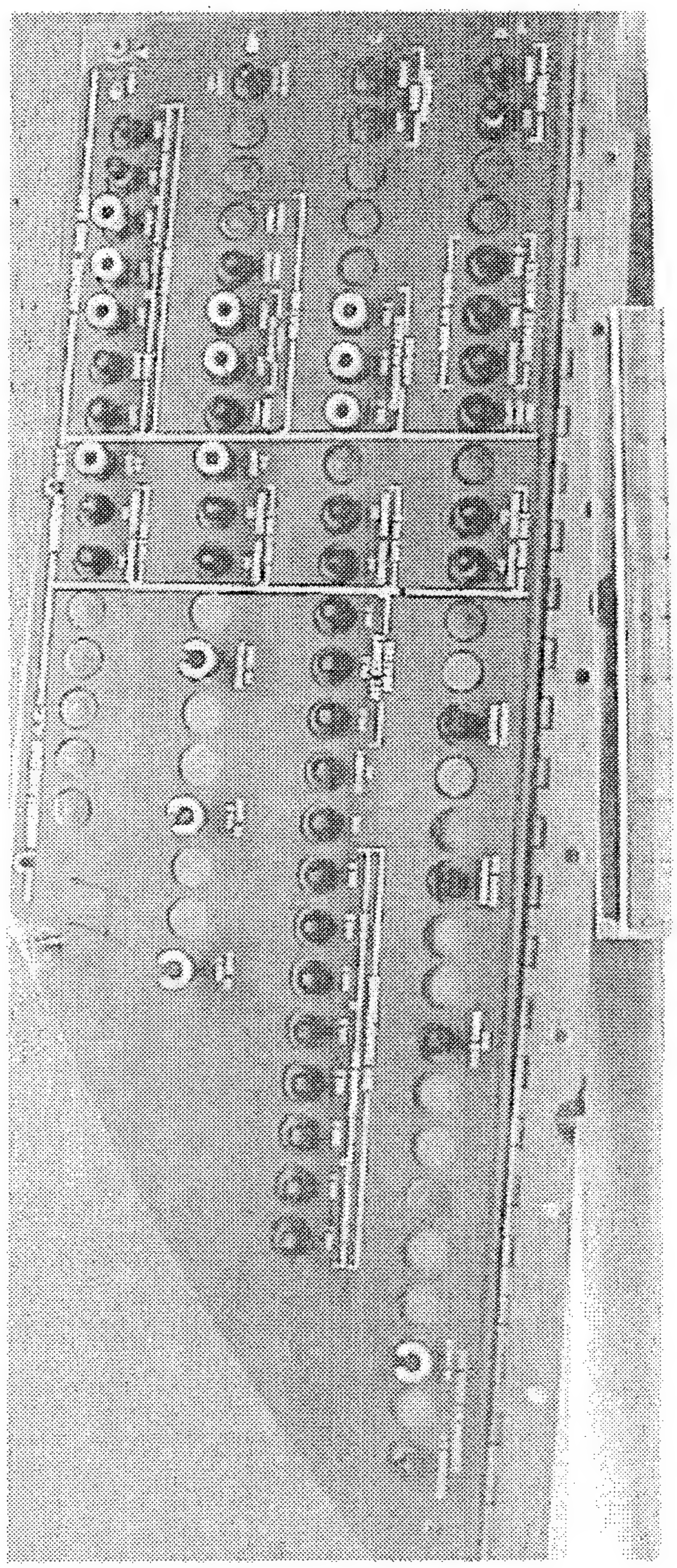
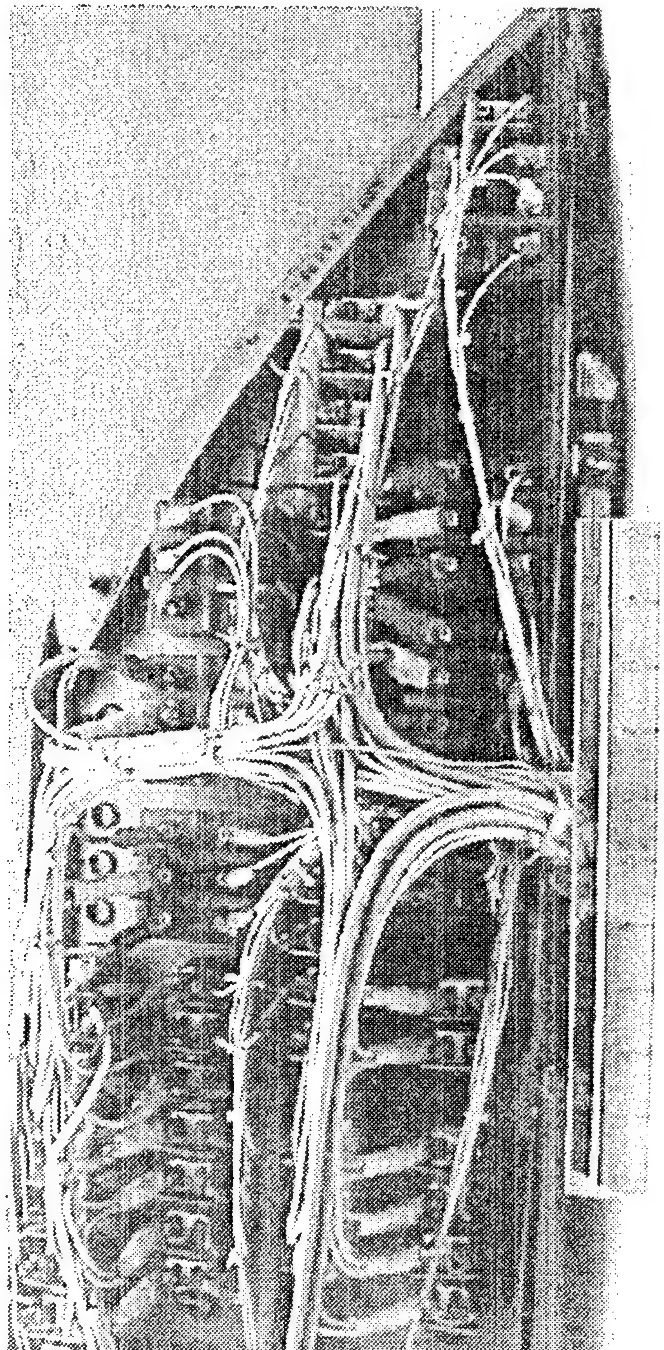
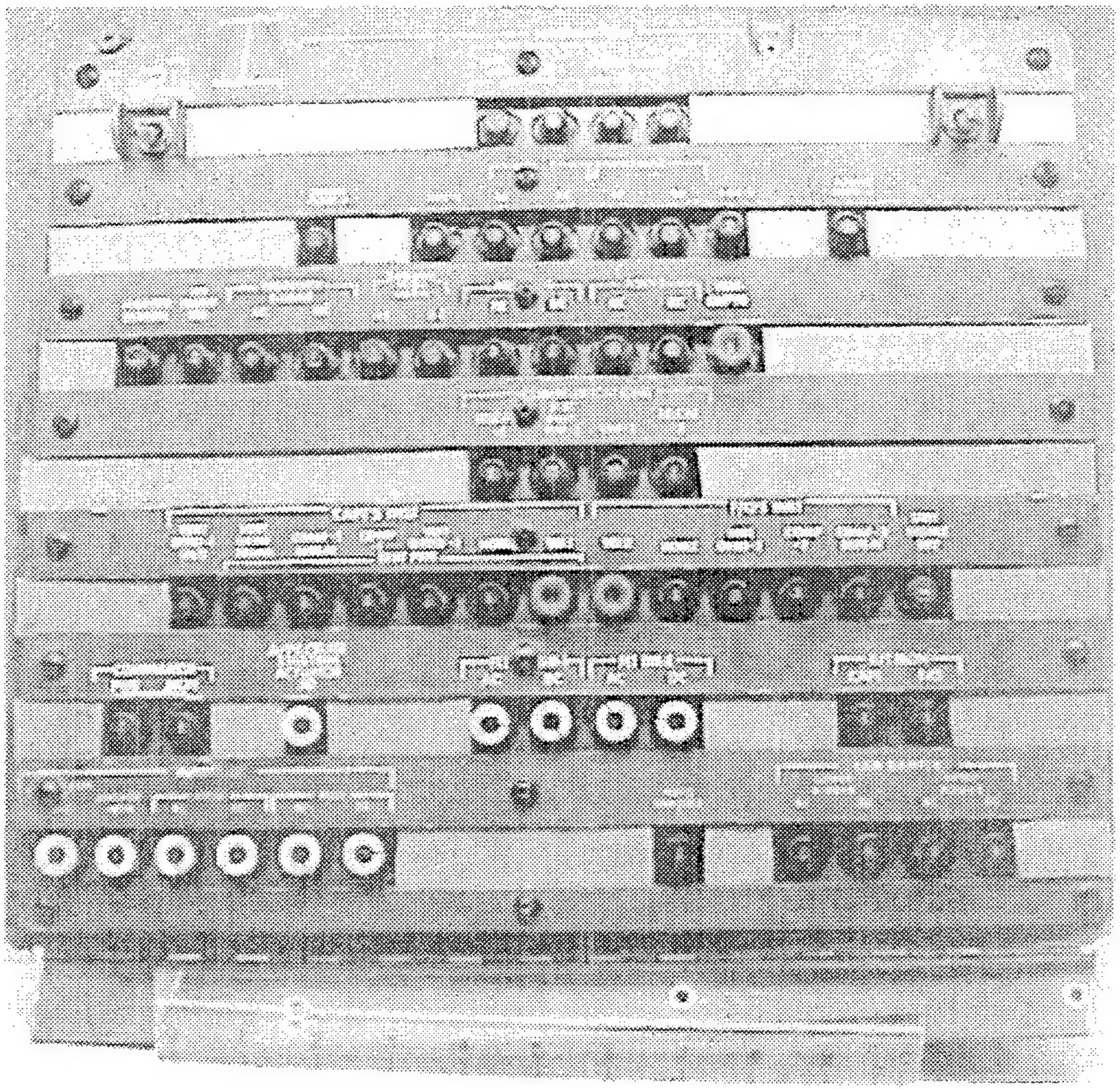
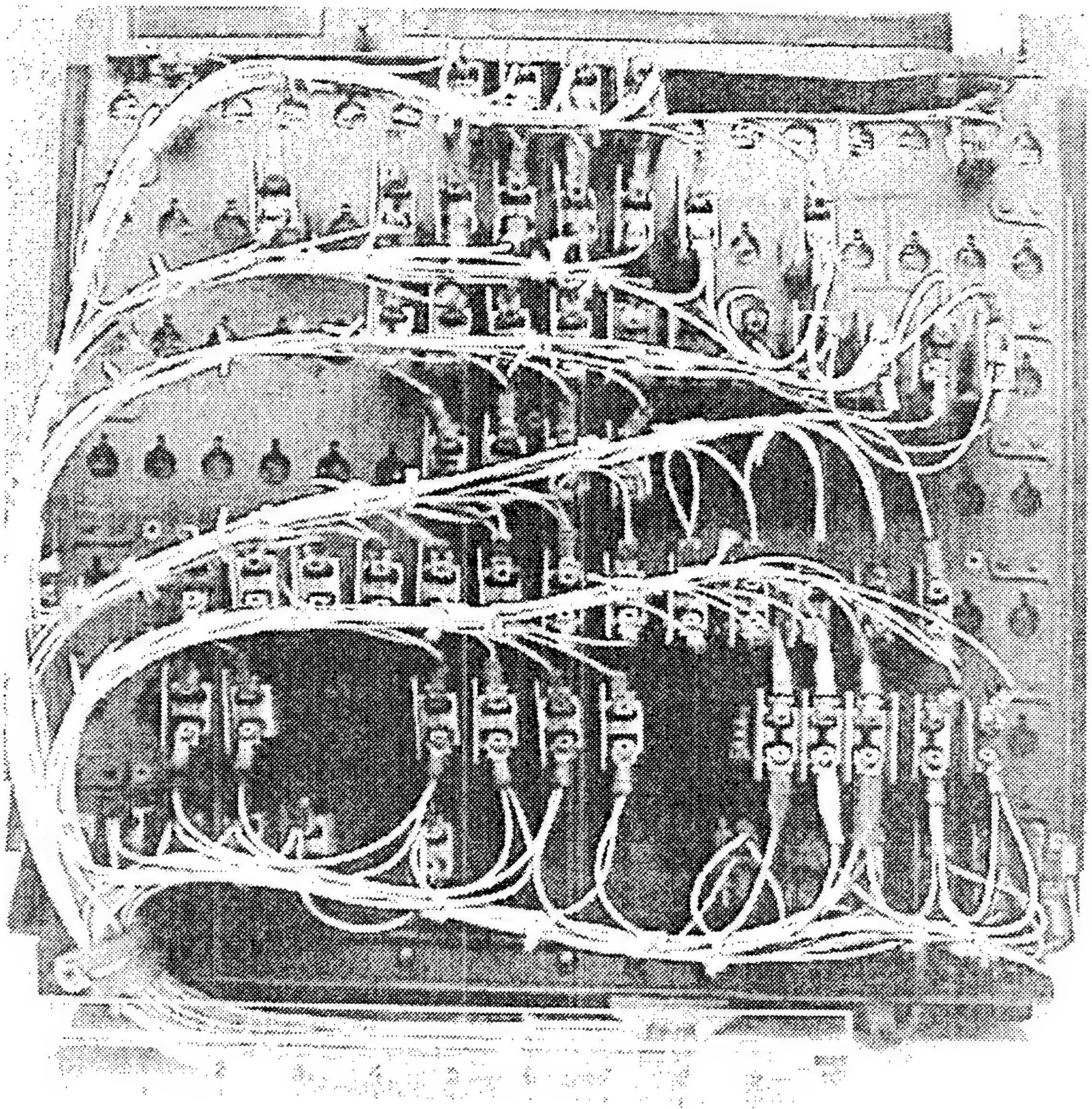
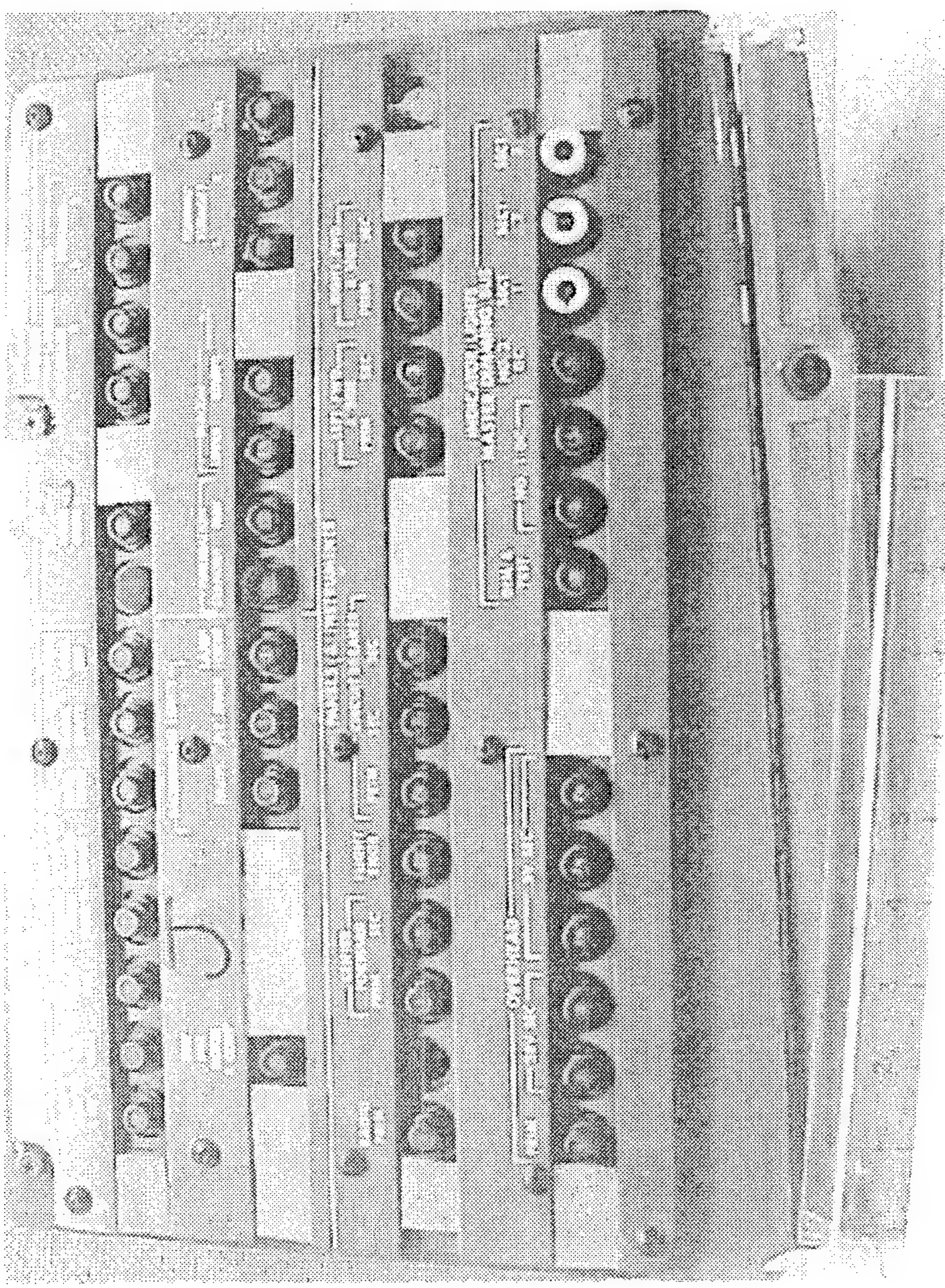


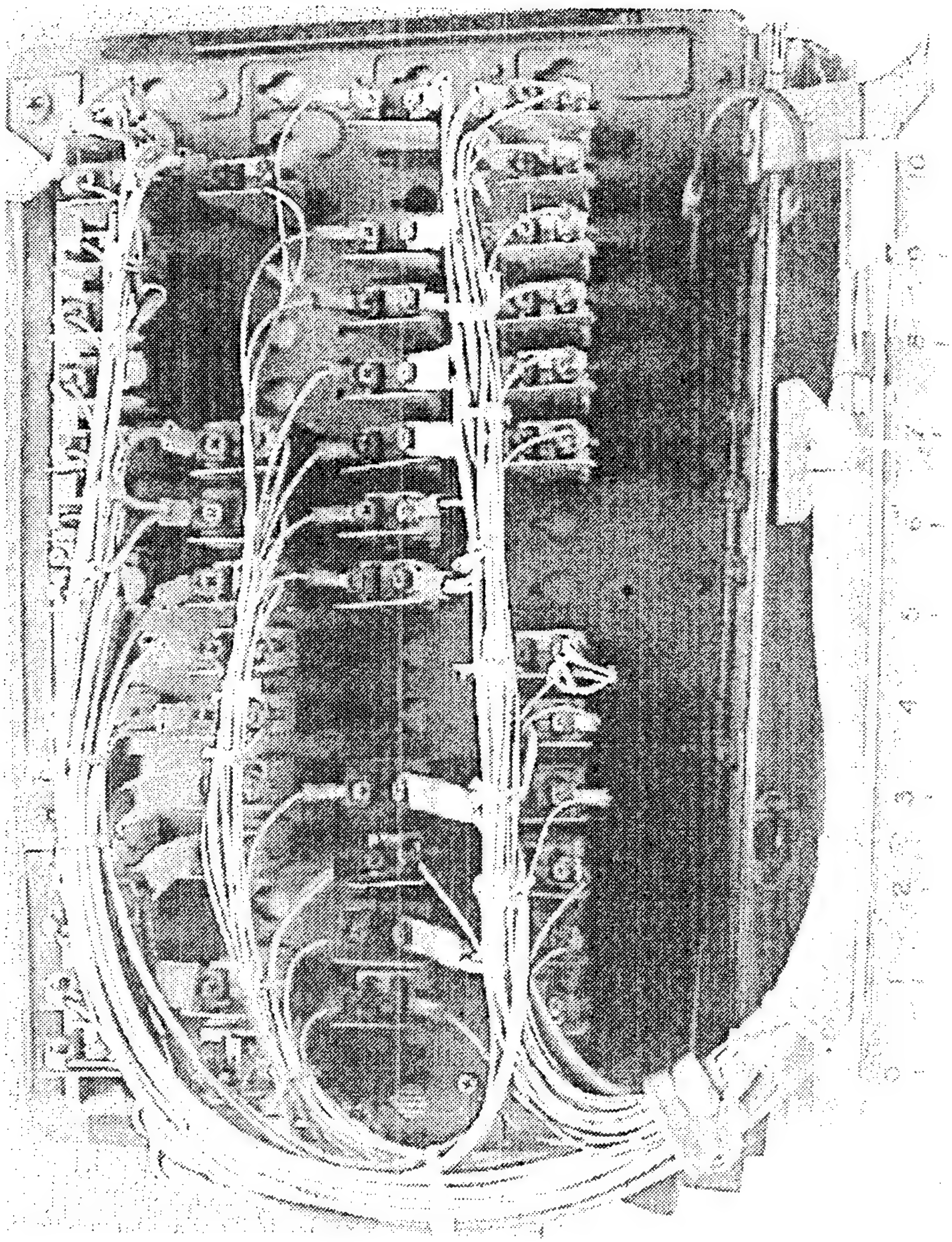


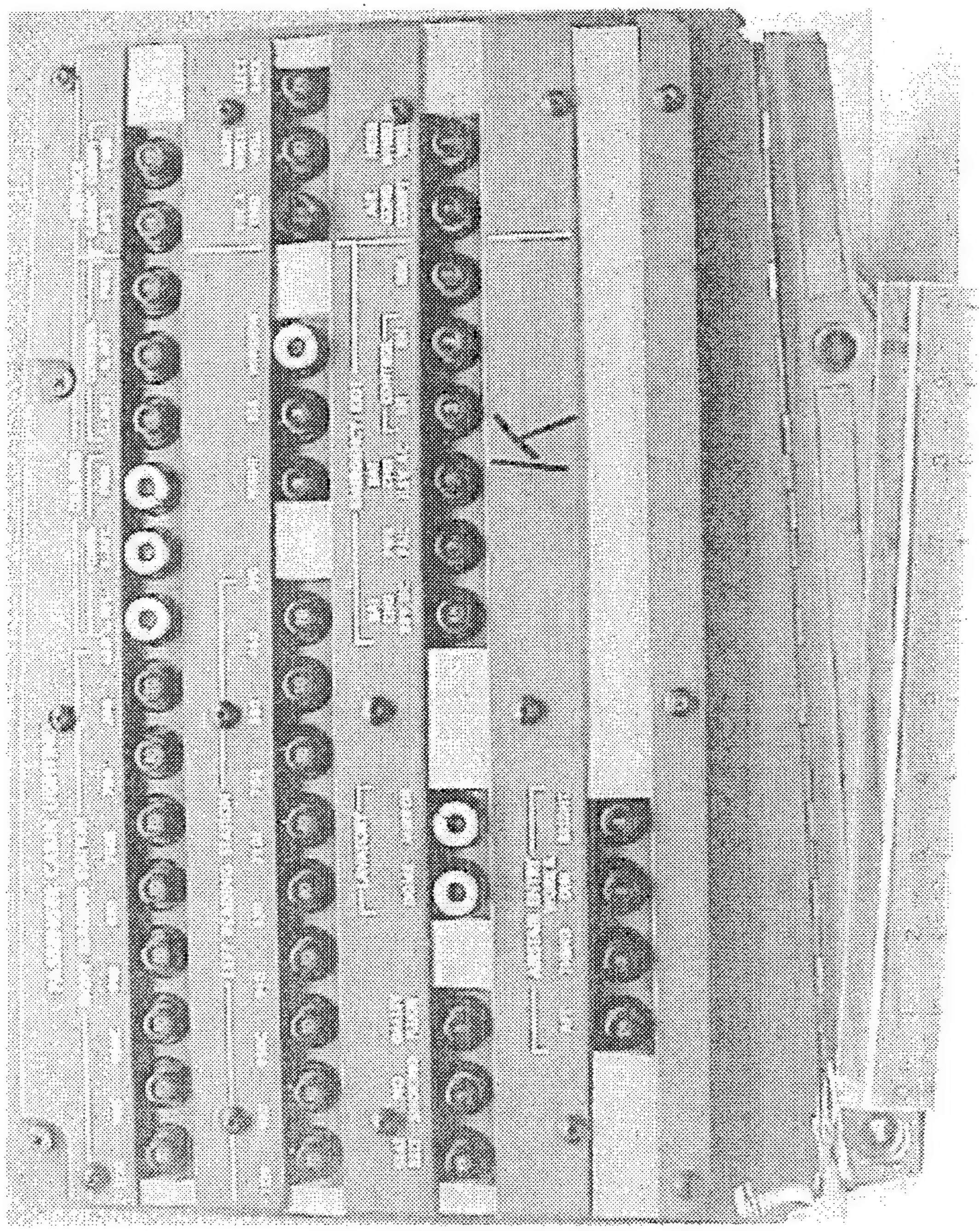


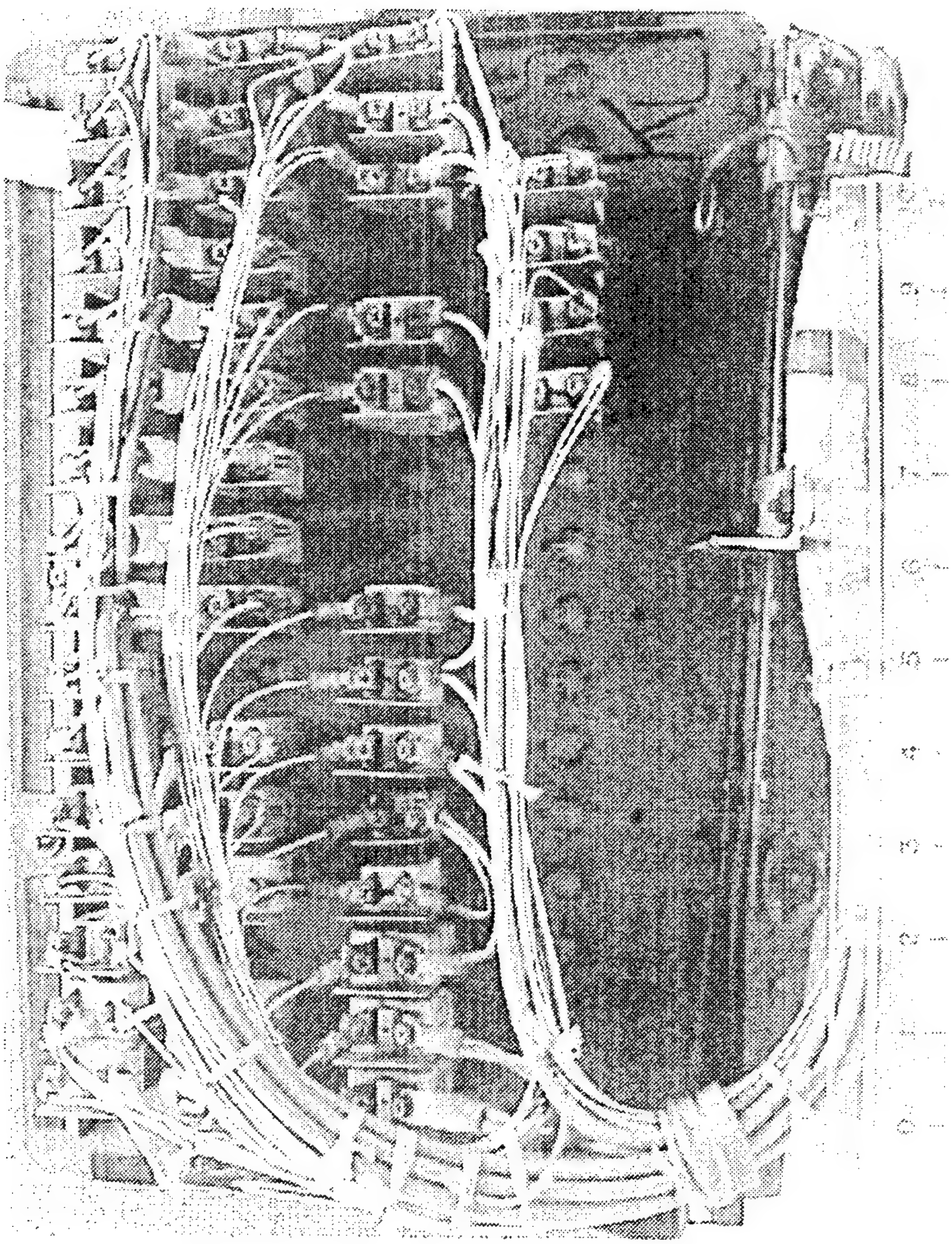


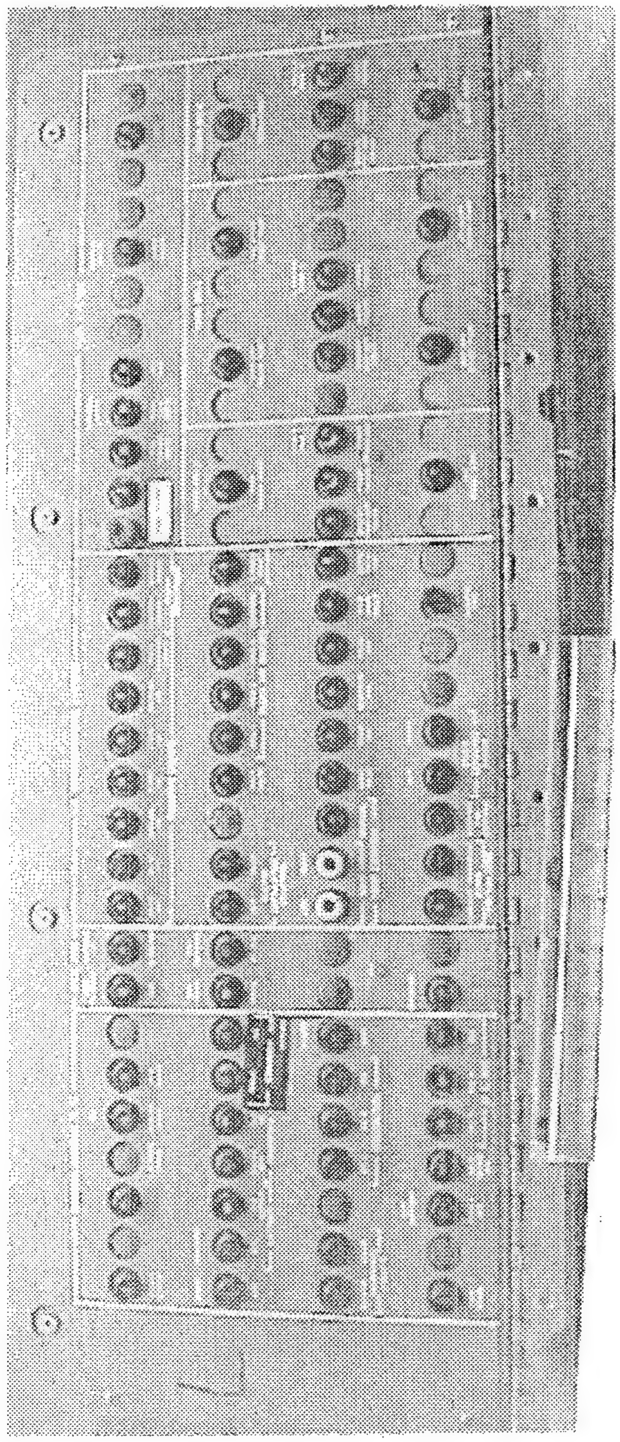


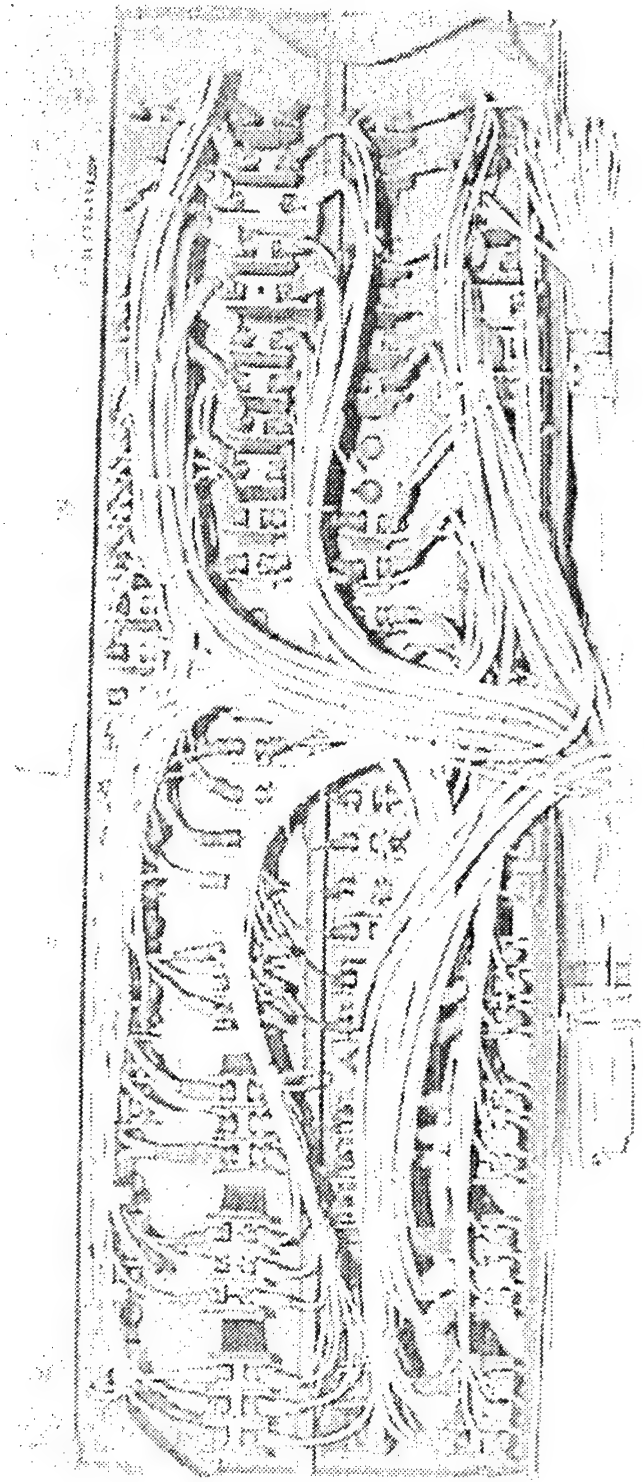












APPENDIX B—CIRCUIT BREAKER SAMPLES AND PHYSICAL INVENTORY

B.1 SAMPLING GUIDELINES.

FAA Circuit Breaker (CB) Sampling Plan

1. Available Specimen information:

a. Breakers from three aircraft submitted. Breakers from only two aircraft are usable.
b. Amp rating range from one-half to 50 Amp.
c. Limited quantity of three phase breakers.
d. In excess of 1000 breakers mounted on 12 panels.
e. Three manufacturers identified. The vast majority of breakers are manufacturer part numbers A though E. A reasonable number are manufacturer part numbers G though N and U. Only a few breakers are manufacturer part numbers P though S.
f. Multiple manufacturer breaker series types. A very high percentage appears to be part numbers A or B(MS22073 type).
g. Amount of lint and dirt varies considerably from panel to panel.
h. Samples of breakers with different date codes for the same manufacturer appears to be available.

2. Assumptions:

a. All CB panels from the same aircraft have similar environmental exposure.
b. The 1.0 Amp breaker and 0.50 breaker have similar applications.
c. The 8.0 Amp, 3-phase breaker and the 7.5 breaker have similar applications.

3. Guidelines for picking samples groups listed below:

a. For each Amp rating group try to pick 10 open breakers.
b. For each Amp rating group try to pick an equal number of breakers from each available manufacturer.
c. For each Amp rating try to pick a random number of circuit types based on the panel information.
d. Do not pick any open breaker with a spacer used to keep it open.

4. Sample Limitations:

a. The results on only two aircraft may not identify breaker trends on all aircraft.
b. Limiting testing to two aircraft improves the sample size for good comparisons
c. Sample details can not be fully obtained until the samples are removed from the panels. Since it is time consuming to record all the installation information for over 1000 breakers, the selection of the 300 breakers (each phase counts as one sample) are based on observations made for each breaker as viewed from the front and back of the panel.
d. To meet the accelerated timeline only single-phase breakers rated with 10 Amperes or less will be submitted to process one testing.

5. Sample Plan:

DC-10 Aircraft:

Amp Rating	Test Sample	Spare Sample	Notes
0.50	32	14	
3.0	31	14	
5.0	37	14	
10.0	2	0	3 phase (6) Mfr. Unknown*
10.0	38	4	
15.0	5	4	
20.0	1	0	

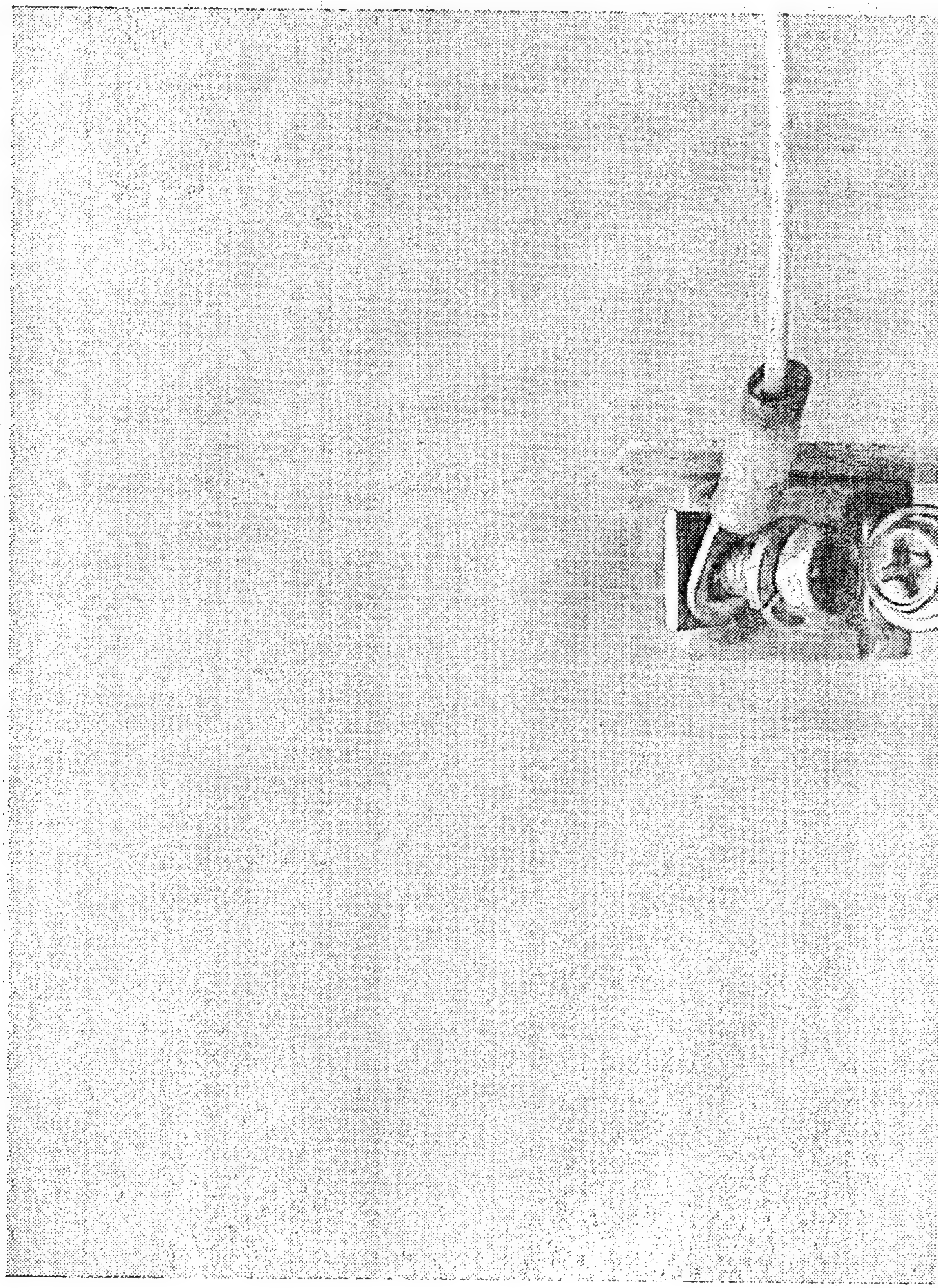
TOTAL:	150	50

727 Aircraft

Amp Rating	Test Sample	Spare Sample	Notes
1.0	26	1	
3.0	26	15	
5.0	27	15	
7.5	21	0	3-phase (21)*
8.0	6	0	3-phase (6)*
10.0	30	16	
15.0	5	1	
20.0	4	2	
50.0	5	0	
TOTAL:	150	50	

* For the purposes of testing a sample is considered to be one phase. Three phase breakers are counted as 3 single-phase breakers, and are ether a 3 single-phase, integral breaker or a bussed breaker.

<u>B.2 CIRCUIT BREAKER EXAMPLES</u>.



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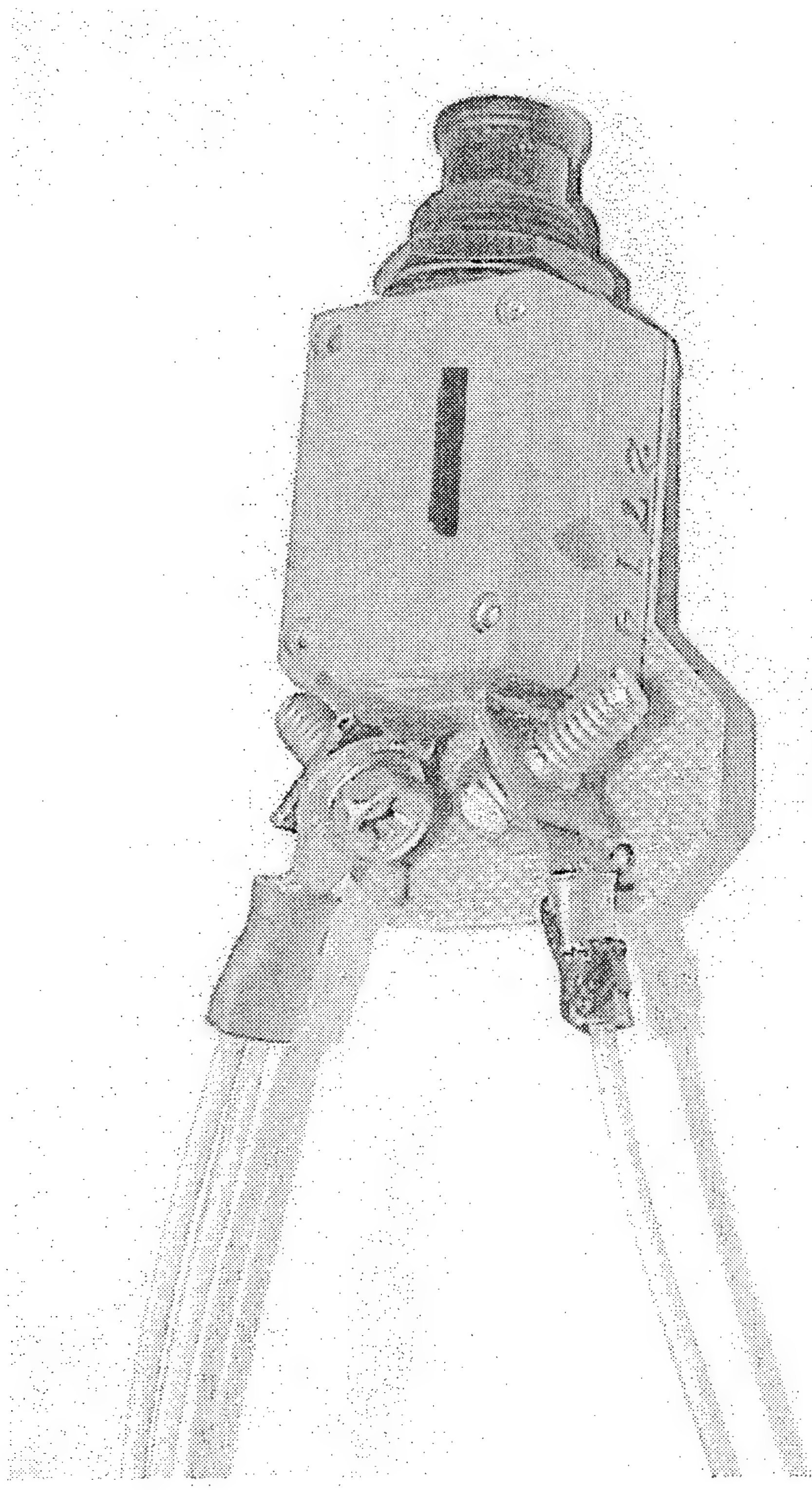

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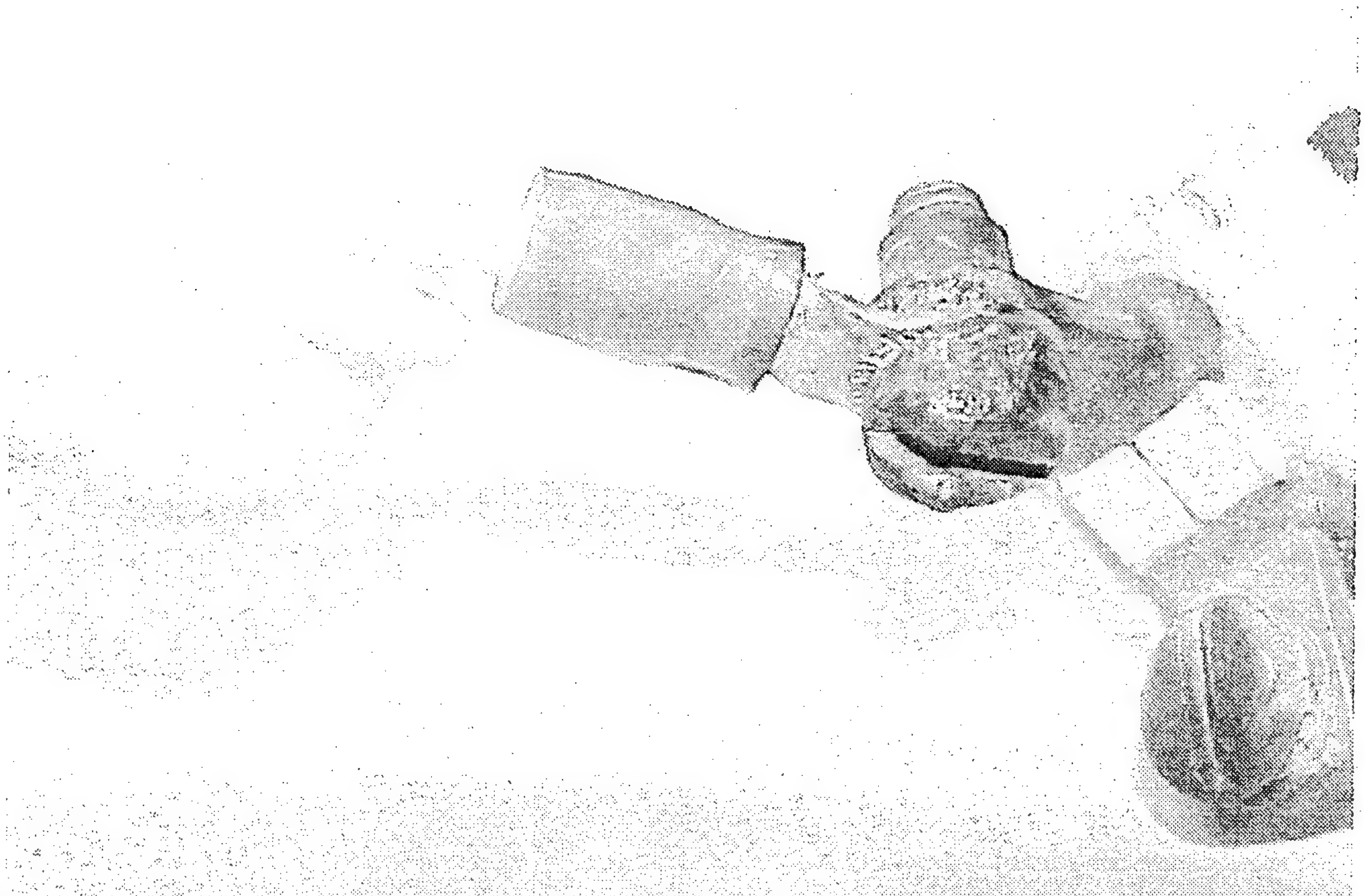

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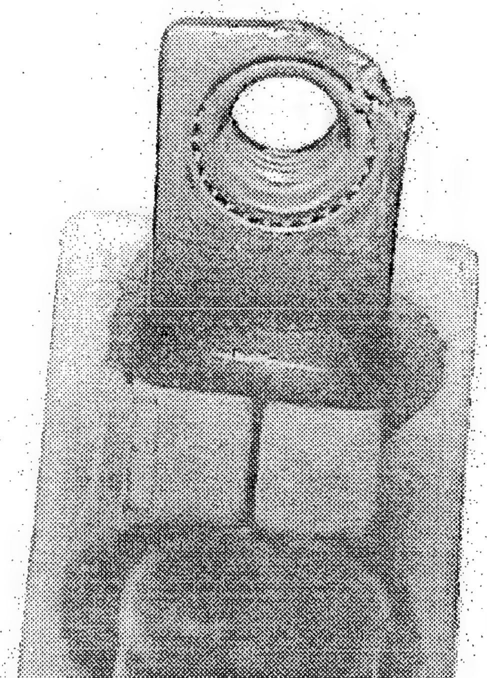


B.3 INVENTORY AND PHYSICAL PROPERTIES.

Circuit Breaker Inventory and Visual Inspection Datasheet

A/C Source	Current Rating: (amps)			
1 - DC-10	A - 1/2	D - 3	G - 8	J - 20
2 - 727-232	B - 1	E - 5	H - 10	K - 50
	C - 2	F - 7.5	I - 15	

Part Numbering Notation ex: *AB103*
A (Panel #), B (current rating), 103 (unique specimen #)
P1 - Prosess 1 Sample
P2- Process 2 sample

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	1	A	D	001	AC Bus 1 / Electrical/28 V AC Bus 1 Xfmr	A-3		1	0974A	Closed	White	N	N	Y	N	Possible liquid spill on body
1	1	A	D	002	AC Bus 1 /Misc/Anti-Skid Control	A-3		1	0974A	Closed	White	N	N	Y	N	Very Dusty/ Possible spillage
1	2	A	D	003	AC Bus 2/Electrical/28V AC Bus 2 XFMR	A-3		1	0874A	Closed	White	N	N	Y	N	Very Dusty/ Possible spillage
1	2	A	D	004	AC Bus 3/ Electrical/ 28V AC Bus 3 XFMR	A-3		1	0874A	Closed	White	N	N	Y	N	Very Dusty/ Possible spillage
1	2	A	D	005	AC Bus 3/ Misc/ Anti Skid Cont	A-3		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	A	D	006	AC GND Service/ Electrical/ 28V AC Bus 3 XFMR Gnd Service	A-3		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	1	A	E	007	DC Bus 2/Cockpit Door Lock	A-5		1	1091A	Open	White	N	N	N	N	
1	1	A	E	008	AC Bus 3/First Officers Seat Power/Phase A	A-5		1	0792A	Closed	White	N	N	N	N	Possible spillage
1	2	A	E	009	DC Bus 2/Cabin Overhead Ltg Overhead Cont	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	A	E	010	DC Bus 1/ Warn Lt Dimming and Test	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	A	E	011	AC Bus 1/ Lighting/ F E Work Table Lt	A-5		1	0874A	Closed	White	N	N	Y	N	Possible spillage
1	1	A	H	012	AC Buss 2/Nose Landing and Taxi Light Left	A-10		1	0974A	Closed	White	N	N	Y	N	Possible spillage
1	2	A	H	013	AC Bus 2 / Misc / Parking Brake Valve	A-10		1	0974A	Closed	White	N	N	Y	N	Dusty
1	2	A	H	014	AC Bus 2/Lighting/Nose Landing & Taxi Rt	A-10		1	0583A	Closed	White	N	N	Y	N	Dusty/Possible spillage
1	2	A	H	015	AC Ground Service / Electrical / TR-2B Input	M-10		A	8739	Closed	White	N	N	Y	N	Very Dusty
1	2	A	H	015	AC Ground Service / Electrical / TR-2B Input	M-10		B	8739	Closed	White	N	N	Y	N	Very Dusty
1	2	A	H	015	AC Ground Service / Electrical / TR-2B Input	M-10		C	8739	Closed	White	N	N	Y	N	Very Dusty
1	2	A	I	018	AC Ground Service / Electrical / 115V AC Utility Outlets / Cockpit	G-15	BACC1 8R15B	1	9011	Closed	White	N	N	N	N	Dusty
1	2	A	I	019	AC Ground Service / Electrical / 115V AC Utility Outlets / Avionics Compt	G-15	BACC1 8R15B	1	9044	Closed	White	N	N	N	N	Dusty
1	1	B	A	020	Battery Direct Bus/Battery Bus Feed/Bat	L-5		1	7207	Closed	Blue	N	N	N	N	
1	1	B	A	021	Battery Direct Bus/Electric Clock	L-5		1	8203	Closed	Blue	N	N	N	N	

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
AD001	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Load wire wrapped back			AAA/1X401A24
AD002	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N				AAA/G51C20
AD003	N	N	N	Inspector's lacquer on one	N	N	N		N	N	N	N				AAA/2X401A24
AD004	N	N	N	Inspector's lacquer on one	N	N	N		N	N	N	N				AAA/3X401B24
AD005	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Extremely Dirty			CCC/G52C20
AD006	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			X351D8A/3X404A24
AE007	N	N	N	Stainless steel screw on line term	N	N	N		N	N	N	N	Extremely Dirty			Buss Bar/M1149C24
AE008	N	N	N	Both screws stainless steel	N	N	N		N	N	N	N	Dirty			AAA/M6C24A
AE009	N	N	N	Inspector's lacquer on one	N	N	N		N	N	N	N	VERY DIRTY			B7-32/L800A22
AE010	N	N	N	Inspector's lacquer on one	N	N	N		N	N	N	N	VERY DIRTY			P176A8/W475K24
AE011	N	N	N	INSPECTOR'S LACQUER	N	N	N		N	N	N	N				BBB / L725A24
AH012	N	N	N	Both screws stainless steel/Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB/1L2408B16
AH013	N	N	N	INSPECTOR'S LACQUER	N	N	N		N	N	N	N	DIRTY			AAA / G50C18
AH014	N	N	N		N	N	N		N	N	N	N	Dirty			BBB/2L2408B16
AH015	N	N	N	Inspector's Lacquer	N	N	N	Very Dusty	N	N	N	N	Gooey/Dirty			X351D8A / X309A16A
AH015	N	N	N	Inspector's Lacquer	N	N	N	Very Dusty	N	N	N	N	Gooey/Dirty			X353D8B / X310A16B
AH015	N	N	N	Inspector's Lacquer	N	N	N	Very Dusty	N	N	N	N	Gooey/Dirty			X353D8C / X311A16C
AI018	N	N	N		N	N	N		N	N	N	N				X353C8C / X426B16
AI019	N	N	N		N	N	N		N	N	N	N				X353C8C / X433A16
BA020	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P27D16N,B759,P486/P22D22
BA021	N	N	N		N	N	N		N	N	N	N	Dirty			P27D16N,B759,P486/D1000A22

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	2	B	A	022	Battery Bus / ACARS	B-0.5	BACC1 8U-05	1	0569A	Closed	White	N	N	N	N	Cap Broken
1	2	B	A	023	Battery Direct Bus / Battery Bus Feeds / L Tie	L-5		1	7417	Closed	Blue	N	N	N	N	Dusty
1	2	B	A	024	Battery Direct Bus / Battery Bus Feeds / R Tie	L-5		1	7417	Closed	Blue	N	N	N	N	Dusty
1	2	B	A	025	Battery Direct Bus / Bat Dir & Left Emer DC Feed	L-5		1	7408	Closed	Blue	N	N	N	N	Dusty
1	2	B	A	026	Battery Direct Bus / Emer Inverter Pwr	L-5		1	7417	Closed	Blue	N	N	N	N	Dusty
1	1	B	D	027	Left Emer AC Bus/ G/ Capt HSI Heading	A-3		1	0374A	Open	White	N	N	N	N	
1	1	B	D	028	Left Emer DC Bus/VHF NAV 1 VOR	A-3		1	0874A	Closed	White	N	N	N	N	
1	1	B	D	029	Right Emer AC Bus/Compass 2	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	030	Right Emer DC Bus / Upper Yaw Damper B	A-3		1	0374A	Open	White	N	N	N	N	
1	2	B	D	031	Battery Bus / DB-VG Switch Unit	A-3		1	0374A	Closed	White	N	N	N	N	Dirty
1	2	B	D	032	Left Emer AC Bus / 28V AC / Capt Mach Airspeed Ind	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	033	Left Emer AC Bus / Lower Yaw Damper A	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	034	Right Emer AC Bus / 28 V AC / Attitude 2	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	035	Battery Bus / Standby Hortz	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	036	Right Emer DC Bus / F/O OBS & Avionic Audio	A-3		1	0374A	Closed	White	N	N	N	N	Dusty
1	2	B	D	037	Right Emer AC Bus / F/O Vert Speed Ind	A-3		1	0374A	Closed	White	N	N	N	N	
1	2	B	D	038	Right Emer AC Bus / 28 V AC / F/O Horizon	B-3	BACC1 8U-3	1	0188A	Closed	White	N	N	N	N	Clean, Looks like new
1	1	B	E	039	Baattery Bus/Aux Hyd Pump Ctl & Lights	B-5		1	0674A	Open	White	N	N	Y	N	
1	1	B	E	040	Battery Direct Bus/Emer & Bat Bus Off Lts	B-5		1	0674A	Closed	White	N	N	N	N	
1	2	B	E	041	Left Emer DC Bus / L Emer DC Bus Sensing	B-5		1	0674A	Open	White	N	N	N	N	
1	2	B	E	042	Right Emer DC Bus / Right Emer DC Bus Sensing	B-5		1	0674A	Closed	White	N	N	N	N	
1	2	B	E	043	Left Emer AC Bus / Capt Pitot Heat	B-5		1	0674A	Closed	White	N	N	N	N	
1	2	B	E	044	Battery Bus / Eng Start & Ignition Cont	B-5		1	0674A	Closed	White	N	N	N	N	

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
BA022	N	N	N		N	N	N		N	N	N	N				RC003-22 / RC062-22
BA023	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N				B7-59, P27D16N, P27C16N / P23B22
BA024	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-59, P27D16N, P27C16N / P24B22
BA025	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-59, P27D16N, P27C16N / P21D22
BA026	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-59, P27D16N, P27C16N / V411D22
BD027	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			B756,1X42DA16/1F2A24
BD028	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			B7-45,P8C10,P8D10/1RN4E22
BD029	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			2F1L24
BD030	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N				P7C10 / 2C642AL20
BD031	N	N	N	3 Lugs on load terminal / Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-51 / 3F7001D-22, F501A22, F501F22
BD032	N	N	N		N	N	N		N	N	N	N	Dirty			B7-56, 1X420A16 / 1F1619R24
BD033	N	N	N	Inspector's Lacquer / Load screw appears older	N	N	N		N	N	N	N	Dirty			X326A10 / 1C1017A20
BD034	N	N	N	Inspector's Lacquer / Line screw is hex head and load screw is standard slotted	N	N	N		N	N	N	N	Dirty			2X420A16 / 2F471D24
BD035	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P6A6 / 3F599D24
BD036	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P7C10 / R23A24
BD037	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1F-12948-300 / 2F1710F24
BD038	N	N	N		N	N	N		N	N	N	N	Dirty	Looks like new wire		2X420A16 / 2F443R20
BE039	N	N	N	Inspector's lacquer	N	N	N	2 lugs on load terminal	N	N	N	N	Dirty			P6A6/M1507A18, M1525A24
BE040	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P4A6/P201A24
BE041	N	N	N	Inspector's lacquer	N	N	N	2 lugs on load terminal	N	N	N	N				P8C10, P2D10, B745 / P216G-22, P216A24
BE042	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P7C10 / P215A24
BE043	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			X326A10 / F2108A22
BE044	N	N	N	Inspector's Lacquer, Line screw darker than load screw	N	N	N		N	N	N	N	Dirty			P6A6 / K201A20

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	1	B	H	045	Battery Bus/Hyd Motor Pumps Cont & Lts/1-3	B-10		1	0674A	Open	White	N	N	N	N	
1	1	B	H	046	Battery Bus/APU Gen Cont	B-10		1	0674A	Closed	White	N	N	N	N	
1	1	B	H	047	Left Emer DC Bus/VHF Comm 1	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	048	Battery Bus / Hyd Motor Pumps cont & Lts / 2-3	B-10		1	0674A	Open	White	N	N	N	N	
1	2	B	H	049	Battery Bus / APU Door Cont	B-10		1	0486A	Closed	White	N	N	N	N	Clean, Looks like new
1	2	B	H	050	Left Emer DC Bus / Cargo Smoke Det & Lts	B-10		1	0785a	Closed	White	N	N	N	N	
1	2	B	H	051	Left Emer DC Bus / Emer Lts Standby	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	052	Battery Bus / Cargo Fire control / Agent 1	B-10		1	0685A	Closed	White	N	N	N	N	
1	2	B	H	053	Battery Direct Bus / Fire X Control / Agent 1	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	054	Battery Bus / AC Bus Cont	B-10		1	1184A	Closed	White	N	N	N	N	
1	2	B	H	055	Right Emer DC Bus / VF Comm 2	B-10		1	1185A	Closed	White	N	N	N	N	
1	2	B	H	056	Right Emer AC Bus / INS 2 Pri Pwr	B-10		1	1185A	Closed	White	N	N	N	N	Clean, Looks like new
1	2	B	H	057	Right Emer DC Bus / VHF Comm 3	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	058	Battery Bus / APU Start Pump	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	059	Battery Direct Bus / Firex Control / Agent 2	B-10		1	0674A	Closed	White	N	N	N	N	
1	2	B	H	089	Right Emer DC Bus / VHF Comm 1	B-10		1	0574A	Closed	White	N	N	N	N	
1	2	B	H	090	Battery Bus / Cargo Fire Control / Agent 2	B-10		1	0686A	Closed	White	N	N	N	N	
1	2	B	H	060	Right Emer AC Bus / TR-3 Input	M-10		A	7	Closed	White	N	N	N	N	
1	2	B	H	060	Right Emer AC Bus / TR-3 Input	M-10		B	7	Closed	White	N	N	N	N	
1	2	B	H	060	Right Emer AC Bus / TR-3 Input	M-10		C	7	Closed	White	N	N	N	N	
1	2	B	I	063	Battery Bus / APU Cont & Fuel Valve	G-15	BACC1 8R15B	1	9408	Closed	White	N	N	N	N	
1	2	B	I	064	Battery Direct Bus / CSD Disc	P-15		1	1173	Closed	White	N	N	N	N	Dirty
1	2	B	J	065	Battery Direct Bus / Gnd Fued Inv Pwr & Hi Level Test	P-20		1	374	Closed	White	N	N	N	N	Dirty
1	1	C	D	066	AC Bus 3/Entertainment Tape	A-3		1	0874A	Open	White	N	N	N	N	Dusty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
BH045	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P6A6/1M1600A16
BH046	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P6A6/4V1A16
BH047	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			PAC10,P7C10,P8 D10/1RV1A16
BH048	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P6A6 / 2M1600A16
BH049	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N	AWG 16 wire in red ring terminal not AWG 18	N	N	N	N	Dirty			P6A6 / K301A16
BH050	N	N	N		N	N	N		N	N	N	N	Dirty	Kapton		P8D10 / W1768Y18
BH051	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P8C10 / L2711A18
BH052	N	N	N		N	N	N	Plastic ferrule on wire in lug insulation	N	N	N	N	Dirty	Kapton		P6A6 / W225A20
BH053	N	N	N	Inspector's Lacquer / 2 lugs on load terminal	N	N	N		N	N	N	N	Dirty			P4A6, 1F-12948-750 / W201B20, W201A20
BH054	N	N	N		N	N	N		N	N	N	N	Dirty			P6A6 / V126A16
BH055	N	N	N		N	N	N		N	N	N	N		Looks like new wire		P7C10 / 2RL84A-20
BH056	N	N	N		N	N	N		N	N	N	N		Looks like new wire		1F-14830-502 / 2F7095B-16
BH057	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P7C10 / 3RV1A16
BH058	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P6A6 / Q653A16
BH059	N	N	N	Inspector's Lacquer / 2 lugs on load and line terminals	N	N	N		N	N	N	N	Dirty			RC062-22, P4A6 / W203B20, W203A20
BH089	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			P7C10 / 2RV1A16
BH090	N	N	N		N	N	N		N	N	N	N	Kapton			P6A6 / W228A20
BH060	N	N	N	Inspector's Lacquer / 2 lugs on line terminals	N	N	N		N	N	N	N	Dirty			X274A8A / X313A16A
BH060	N	N	N	Inspector's Lacquer / 2 lugs on line terminals	N	N	N		N	N	N	N	Dirty			X275A8B / X314A16B
BH060	N	N	N	Inspector's Lacquer / 2 lugs on line terminals	N	N	N		N	N	N	N	Dirty			X276A8C, 1F-14830-502 / X315A16C
BI063	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N				K259D10, K259A18 / P6A6
BI064	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-52, P4A6 / E1050A16
BJ065	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			B7-52, P4A6 / E875A16
CD066	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228F8A / RZ600A24

Panel Info: A/C	Circuit Breaker Information: P1 or P2	Sample Number: Panel #	Sample Number: Current Rating	Sample Number: Specimen Number	Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Circuit Breaker Visual Inspection — Breaker Description: Open/ Closed?	Breaker Description: Body Color	Breaker Condition: Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	1	C	D	067	AC Bus 3/ Elev Load Feel & Flap Lim	B-3	BACC1 8U3	1	0489A	Closed	White	N	N	N	N	
1	1	C	D	068	AC Bus 3-TAS/SAT Inc	B-3	BACC1 8U3	1	0887A	Closed	White	N	N	N	N	
1	2	C	D	069	AC Bus 3 / 28V AC/ Capt & F/O RMI VOR Bearing Nav 2	A-3		1	0874A	Open	White	N	N	N	N	Dusty
1	2	C	D	070	AC Bus 3 / Main Multiplexer	A-3		1	0874A	Open	White	N	N	N	N	Dusty
1	2	C	D	071	AC Bus 1 / Misc / Left Avionics 28V AC Bus Xformer	A-3		1	0874A	Closed	White	N	N	N	Y	Dusty
1	2	C	D	072	DC Bus 3 / Hor Stab Trim Rate Cont 2	K-3		1	8713	Closed	Blue	N	N	N	N	
1	2	C	D	073	AC Bus 1 / Misc / Attitude 3	A-3		1	0874A	Closed	White	N	N	N	N	
1	2	C	D	074	AC Bus 1 / Navigation / ILS 1	B-3	BACC1 8U-3	1	1069A	Closed	White	N	N	N	N	Clean, Looks like new
1	2	C	D	075	DC Bus 1 / Elev Load Feel & Flap Lim 1	B-3	BACC1 8U-3	1	0590A	Closed	White	N	N	N	N	Clean, Looks like new
1	2	C	D	076	DC Bus 3 / Standby Altimeter Vibrator	A-3		1	0874A	Closed	White	N	N	N	N	
1	2	C	D	077	AC Bus 1 / Communication / Sel Cal 1	A-3		1	0874A	Closed	White	N	N	N	N	
1	2	C	D	078	DC Bus 3 / Flight Guidance 2 / Control Panel	A-3		1	0874A	Closed	White	N	N	N	N	
1	1	C	E	079	AC Bus 1/Navigation/ATC-1	A-5		1	0289A	Closed	White	N	N	N	N	
1	2	C	E	080	AC Bus 1 / Communication / Service Interphone / Call Reset	A-5		1	0874A	Open	White	N	N	N	N	Dusty
1	2	C	E	081	DC Bus 1 / Flight Guidance 1 / Roll	A-5		1	0674A	Closed	White	N	N	N	N	Dusty
1	2	C	E	082	DC Bus 3 / F/O Stick Shaker	A-5		1	0874A	Closed	White	N	N	N	N	
1	2	C	E	083	AC Bus 1 / Navigation / TCAS	A-5		1	0289A	Closed	White	N	N	N	N	
1	1	C	H	084	AC Bus 1 / Navigation / INS-1 Pri Pwr	H-10		1	7807	Closed	White	N	N	N	N	
1	2	C	H	085	DC Bus 1 / Flight Guidance 1 / Pitch	A-10		1	0974A	Closed	White	N	N	N	N	
1	2	C	H	086	DC Bus 3 / Flight Guidance 2 / Pitch	A-10		1	1087A	Closed	White	N	N	N	N	Clean, Looks like new

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
CD067	N	N	N	Lock washers against lugs/Inspector's lacquer on lug ring	N	N	N		N	N	N	N	Dirty			AAA, 1X228F8A / 2C1218M20
CD068	N	N	N	Both lock washers against lugs/Inspector's lacquer	N	N	N		N	N	N	N	Dirty			28V AC / F1734F22
CD069	N	N	N	nspector's Lacque	N	N	N		N	N	N	N	Dirty			B7-43, 2X417A16 / 2F151A24
CD070	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228F8A / RZ650A24
CD071	N	N	N	Inspector's Lacquer / Line terminal blackened from arcing	N	N	N	Indication of arcing	N	N	N	N	Dirty	Buss wire not original		AAA-16, 1X228F8A / 1XL16A22
CD072	N	N	N		N	N	N		N	N	N	N	Dirty			P178D8 / 2C1236A20
CD073	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1X417A16 / 3F508A22
CD074	N	N	N		N	N	N		N	N	N	N	Dirty			AAA, 1X228F8A / 1RN21D22
CD075	N	N	N	Lock washers against lugs	N	N	N		N	N	N	N	Dirty			P176AD8 / 1C1227L20
CD076	N	N	N	Inspector's Lacquer on line terminal	N	N	N		N	N	N	N	Dirty			P178B8 / F1519A22
CD077	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228F8A / RV217A22
CD078	N	N	N	Inspector's Lacquer on line terminal	N	N	N		N	N	N	N	Dirty			P178D8 / 2C1812E20
CE079	N	N	N		N	N	N		N	N	N	N	Dirty		CD071V1, CD071V2, CD071V3, CD071V4	AAA, 1X228F8A / 1SX36A-22
CE080	N	N	N	Inspector's Lacquer / 2 lugs on load terminal	N	N	N		N	N	N	N	Dirty			P176D8 / RZ901G18, RZ901A22
CE081	N	N	N	Inspector's Lacquer on load terminal	N	N	N		N	N	N	N	Dirty			P176D8 / 1C703A20
CE082	N	N	N	Inspector's Lacquer / 2 terminals on load terminal	N	N	N		N	N	N	N	Dirty			P178D8 / 2F2001A20, 2F2001K20
CE083	N	N	N		N	N	N		N	N	N	N	Dirty	Red		AAA, 1X228F8A / TQ7000A-20
CH084	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			1F-9327-2,BBB/1F7095B16
CH085	N	N	N	Inspector's Lacquer / 2 lugs on Load terminal	N	N	N		N	N	N	N	Dirty			P178D8 / 1C702A16, 1C702B16
CH086	N	N	N	Inspector's Lacquer on ring terminals only / 2 lugs on load terminal	N	N	N		N	N	N	N	Dirty			P178D8 / 2C102A16, 2C102B16

Panel Info	Circuit Breaker Information										Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition					
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	2	C	H	087	DC Bus 1 / Communication / HF Comm 1	A-10		1	1185A	Closed	White	N	N	N	N	
1	2	C	H	088	AC Bus 3/ Weather Rader 2 / Xcvr	A-10		1	0974A	Closed	White	N	N	N	N	
1	1	D	A	091	DC Sys / Aux Hyd Pump 1	L-5		1	9346	Closed	Blue	N	N	N	N	
1	1	D	A	092	DC Sys / DC X Tie	L-5		1	7417	Closed	Blue	N	N	N	N	
1	1	D	A	093	DC Sys / TR 3 Output	L-5		1	7425	Closed	Blue	N	N	N	N	Very Dusty
1	1	D	A	094	Fuel / Gen Bus / AC Bus 1 / Fuel Pump Power / Tank 3 Trans	L-5		1	7408	Closed	Blue	N	N	N	N	Very Dirty
1	1	D	A	095	Fuel / Gen Bus / AC Bus 2 / Fuel Pump Power / Tank 3 Aft	L-5		1	7439	Closed	Blue	N	N	N	N	Very Dusty
1	2	D	A	096	AC Gnd Service / Aux Hyd Pump 2	L-5		1	9350	Open	Blue	N	N	Y	N	Very Dusty
1	2	D	A	097	AC Gnd Service / Cockpit Ground Service Bus / A Phase	L-5		1	9137	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	098	AC Gnd Service / Cockpit Ground Service Bus / C Phase	L-5		1	9137	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	099	AC Gnd Service / Fwd & Mid Cabin Gnd Service Bus / B Phase	L-5		1	8823	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	100	AC Gnd Service / Over Wing & Aft Cabin Gnd Service Bus / A Phase	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	101	AC Gnd Service / Over Wing & Aft Cabin Gnd Service Bus / C Phase	L-5		1	9211	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	102	AC Bus 1 / DC Sys / DC Bus Tie Sensing / Right	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	103	AC Bus 1 / DC Sys / DC Bus 1	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	104	AC Bus 1 / Gen Bus / AC Bus 1 / B Phase	L-5		1	7423	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	105	AC Bus 1 / Gen Bus / Cabin Bus 1	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	106	AC Bus 1 / Gen Bus / TR 1 Input	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	107	AC Bus 1 / Gen Bus / Fuel / Fuel Pump Power / Tank 2 Fwd	L-5		1	7408	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	108	AC Bus 2 / DC Sys / TR 2A Output	L-5		1	7417	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	109	AC Bus 2 / DC Sys / DC Bus 2	L-5		1	7445	Closed	Blue	N	N	Y	N	Very Dusty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discolor ation?	High Temp Expos?	Other Visual Comments			
CH087	N	N	N		N	N	N		N	N	N	N	New			P176D8 / 1RL84A-20 / B1-1227
CH088	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			AAA, 3X228F8A / 2SS20E18
DA091	N	N	N	Screws are too short	N	N	N		N	N	N	N	Dirty			V354B16N,V354A 16N/M1404D22
DA092	N	N	N	2 wires in load lug/Inspector's lacquer	N	N	N		N	N	N	N	Dirty			V380B16N,V380A 16N/P161D22
DA093	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			V382B16N,V382A 16/P88A22
DA094	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			1V57A16N/3Q376 D22
DA095	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			2V57616N/3Q371 D22
DA096	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N		N	N	N	N	Dirty			V354B16N,V354A 16N / M1402D22
DA097	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N		N	N	N	N	Dirty			V354B16N, V354A16N / V351D22
DA098	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N		N	N	N	N	Dirty			V354B16N, V354A16N / V353D22
DA099	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N		N	N	N	N	Dirty			V354B16N, V354A16N / V452A22
DA100	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			V354B16N, V354A16N / V457A22
DA101	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			V354B16N, V354A16N / V459A22
DA102	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			V381A16N, V381B16N / P34B22
DA103	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			V381A16N, V381B16N / P182B22
DA104	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1V57A16N, 1V57B16N / 1V52D22
DA105	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1V57A16N, 1V57B16N / V470E22
DA106	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1V57A16N, 1V57B16N / V376A22
DA107	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			1V57A16N, 1V57B16N / 2Q371D22
DA108	Y	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			V380B16N, V380A16N / P86A22
DA109	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			V380B16N, V380A16N / P184B22

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	2	D	A	110	AC Bus 2 / Gen Bus / AC Bus 2 / B Phase	L-5		1	9129	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	111	AC Bus 2 / Gen Bus / Gnd Service Tie Relay Cont	L-5		1	7417	Closed	Blue	N	N	N	N	
1	2	D	A	112	AC Bus 2 / Gen Bus / Fuel / Fuel Pump Power / Tank 1 Trans	L-5		1	7423	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	113	AC Bus 3 / Gen Sys / AC Bus 3 / B Phase	L-5		1	7423	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	114	Ac Bus 3 / Gen sys / Cabin Bus 3	L-5		1	7408	Closed	Blue	N	N	Y	N	Very Dusty
1	2	D	A	115	AC Bus 3 / Gen Sys / Fuel / Fuel Pump Power / Tank 3 Fwd	L-5		1	7425	Closed	Blue	N	N	Y	N	Very Dusty
1	1	D	E	116	Ice & Rain / AC Bus 2 / Tap Probe Heat	TI		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	1	D	E	117	Ice & Rain / AC Bus 3 / R Angle Attack Heat	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	1	D	E	118	Cabin Press & Pneumatics / Ac Bus 2 / Cabin Pass Auto Cont	A-5		1	0996	Closed	White	N	N	Y	N	Very Dusty
1	2	D	E	119	AC Bus 1 / 28 V AC / Air Conditioning / Left Angle Attack / Heat	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	120	AC Bus 2 / Air Conditioning / Cabin Manual Temp Cont	A-5		1	0674A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	121	AC Bus 2 / Ice & Rain / Lavatory Drain Mast Heat / Fwd	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	122	AC Bus 3 / Air Conditioning / Auto Temp Cont Pack 1	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	123	DC Bus 1 / Air Conditioning / Cabin Temp Ind	A-5		1	0674A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	124	DC Bus 1 / Ice & Rain / L Windshield Anti-Ice	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	125	AC Bus 3 / Cabin Press & Pneumatics / Pass Oxy Release L/R Aft Cabin	A-5		1	0674A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	126	DC Bus 2 / Cabin Pres & Pneumatics / Cabin Pres Relief Lt	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty
1	2	D	E	127	DC Bus 2 / Air Conditioning / Duct Avionic Compt Overht Lt	A-5		1	0874A	Open	White	N	N	Y	N	Very Dusty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
DA110	N	N	N	Inspector's Lacquer on ring terminal but not on screws	N	N	N		N	N	N	N	Dirty			2V57B16N, 2V57A16N / 2V52D22
DA111	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			2V57B16N, 2V57A16N / V624E22
DA112	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			2V57B16N, 2V57A16N / 1Q381D22
DA113	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			3V57B16N, 3V57A16N / 3V52D22
DA114	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			3V57B16N, 3V57A16N / V474E22
DA115	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			3V57B16N, 3V57A16N / 3Q381D22
DE116	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC / F2132C20
DE117	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB / 3F2140A20
DE118	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC / H250E24
DE119	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			1X403B16 / 1F2141A20
DE120	N	N	N	Inspector's lacquer / 3 lugs on load terminal	N	N	N		N	N	N	N	Dirty			2X229D8B / 3H650A22, 4H650A22, 5H650A22
DE121	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			2X229D8B / H1400A22
DE122	N	N	N	Inspector's Lacquer	N	N	N		N	N	N	N	Dirty			AAA, 3X228D8A / 1H857A22
DE123	N	N	N	Inspector's lacquer / 3 lugs on load terminal	N	N	N		N	N	N	N	Dirty			P176B8 / D318B24, D318C24, D318E24
DE124	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P176B8 / 1H1102E22
DE125	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC, 3X230D8C / W329R18
DE126	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P177B8 / D125C24
DE127	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P177B8 / H500E22

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	2	D	E	128	DC Bus 2 / Air Conditioning / Trim Air Manual Shutoff	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	E	129	DC Bus 2 / Cabin Pres & Pneumatics / Pneu Temp Hi Lt Eng 2	A-5		1	0291A	Closed	White	N	N	Y	N	Very Dusty / Blue printing
1	2	D	E	130	DC Bus 3 / Cabin Pres & Pneumatics / Hi Stage Open Lt / Eng 3	A-5		1	0874A	Closed	White	N	N	Y	N	Evidence of spillage / Very Dusty
1	2	D	E	131	DC Bus 3 / Cabin Pres & Pneumatics / Manifold Failure Det Lt Loop 3	A-5		1	0874A	Closed	White	N	N	Y	N	Evidence of spillage / Very Dusty
1	2	D	E	132	AC Bus 3 / 28 V AC / Air Conditioning / R Angle Attack Heat	A-5		1	0874A	Closed	White	N	N	Y	N	Evidence of water spillage / Very Dusty
1	2	D	E	133	AC Bus 2 / Air Conditioning / Cockpit Auto Temp Cont	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	E	134	AC Bus 1 / Cabin Pres & Pneumatics / Pneu Sys Cont Eng 1	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	E	135	DC Bus 3 / Engine / Oil Temp Ind / Eng 3	A-5		1	0674A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	E	136	DC Bus 1 / Hydraulic / Hyd Temp Ind 1	A-5		1	0874A	Closed	White	N	N	Y	N	Very Dusty
1	1	D	H	137	AC Bus 3/Radio Rack Fan/ A Phase	A-10		1	1274A	Closed	White	N	N	Y	N	Very Dusty
1	1	D	H	138	AC Bus 3/Static Port Heat	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	139	AC Bus 3 / Cabin Press & Pneumatics / Radio Rack Fan / Phase B	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	140	AC Bus 3 / Cabin Press & Pneumatics / Radio Rack Fan / Phase C	A-10		1	1274A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	141	AC Bus 3 / Ice & Rain / R Windshield Defog	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	142	AC Bus 3 / Ice & Rain / R Clearview Defog	A-10		1	0991A	Closed	White	N	N	Y	N	Very Dusty / Blue printing
1	2	D	H	143	AC Bus 3 / Ice & Rain / R Windshield Anti-ice / Cont	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	144	AC Bus 1 / Air Conditioning / Avionic Compartment Fan / Phase A	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
DE128	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P177B8 / H523A22
DE129	N	N	N	Inspector's lacquer on ring terminals only	N	N	N		N	N	N	N	Dirty			P177B8 / 2H2050C24
DE130	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty	Only 3 strands holding wire in bus lug		P178B8 / 3H1950C24
DE131	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P178B8 / 3H1800A22
DE132	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			3X403B16 / 3F2141A20
DE133	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB, 2X229D8B / 1H655A22
DE134	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228D8A / 1D1250E22
DE135	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P178C8 / 3E551B22
DE136	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P176C8 / 1D900B22
DH137	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA/H121A20A
DH138	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC/3F2132D18
DH139	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB, 3X229D8B / H122A20B
DH140	N	N	N		N	N	N		N	N	N	N	Dirty			CCC, 3X230D8C / H123A20C
DH141	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB, 3X229D8B / 3H1201C20
DH142	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC, 3X230D8C / 3H1200C20
DH143	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA, 3X228D8A / 3H1100C20
DH144	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228D8A / H106B20A

Panel Info		Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	2	D	H	145	AC Bus 1 / Air Conditioning / Avionic Compartment Fan / Phase C	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	146	AC Bus 1 / Ice & Rain / L Windshield Defog	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	147	AC Bus 3 / Ice & Rain / L Clearview Defog	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	148	AC Bus 3 / Ice & Rain / L Windshield Anti-ice / Cont	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	H	149	AC Bus 1 / Ice & Rain / L Static Port Heat	A-10		1	0974A	Closed	White	N	N	Y	N	Very Dusty
1	2	D	I	150	DC Bus 1 / Ice & Rain / L Windshield Wiper / Motor	H-15		1	7413	Open	White	N	N	Y	N	Very Dusty
2	1	E	B	192	Engine #3 / xfmr ind lts / oil temp / press	B-1	BACC18U-1	1	1268A	Closed	White	N	N	Dusty	N	
2	2	E	B	151	Fire Protection System / Ovht Lwr Aft Body / Struts W Well	B-1	BACC18U-1	1	1168A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	B	152	Engine No. 1 / Xfmr / Ind Lts Oil Temp & Press	B-1	BACC18U-1	1	0569A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	D	153	Landing Gear / Aural Warn	C-3	BACC18Z3R	1	9548	Closed	Aqua	N	N	Y	N	Discolored line terminal
2	2	E	D	154	Eng / Cooler Valve Control	B-3	BACC18U-3	1	0569A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	D	155	Fire Protection System / Engine Detection A / No. 2	B-3	BACC18U-3	1	0569A	Closed	White	N	N	Y	N	Very Dusty
2	1	E	E	191	Extinguisher Sys / Rt bottles	G-5	BAC-C18R5B	1	7350	Closed	White	N	N	Y	N	
2	2	E	E	156	Gen No. 2 / Cooler Shutoff	B-5	CC18U-	1	1173A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	E	157	Landing Gear / Anti-skid / Parking Brake / outbd	B-5	CC18U-	1	1173A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	E	158	Eng / Trim	B-5	BACC18U-5	1	1173A	Closed	White	N	N	Y	N	Very Dusty
2	1	E	H	184	Engine No.3/ Ignition/ Start	B-10	BACC18U10	1	0575A	Closed	White	N	N	Clean	N	Yellow cap on button
2	2	E	H	159	Engine No. 1 / Ignition / Start	B-10	BACC18U10	1	0873A	Closed	White	N	N	Y	N	Very Dusty
2	2	E	H	160	Engine No. 2 / Ignition / Start	B-10	BACC18U10	1	0873A	Closed	White	N	N	Y	N	Very Dusty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
DH145	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC, 1X230D8C / H110B20C
DH146	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			BBB, 1X229D8B / 1H1201C20
DH147	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC, 1X230D8C / 1H1200C20
DH148	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			AAA, 1X228D8A / 1H1100C20
DH149	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			CCC, 1X230D8C / 1F2132D18
DI150	N	N	N	Inspector's lacquer	N	N	N		N	N	N	N	Dirty			P176B8 / 1M1175A12
EB192	N	N	N		N	N	N	Lock washer against load lug, 2 wires in line lug	N	N	N	N				W480-231-12, W480-232-12 / W484-047-22 AG
EB151	N	N	N	Lock washer is against the lug	N	N	N	2 lugs on load terminal / 2 wires in one of the lugs	N	N	N	N	Dirty			W480-154-8 / W484-053-22 AG, W484-051-22 AG, W484-052-22 AG
EB152	N	N	N	Lock washer is against the lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-201-12, W480-202-12 / W484-046-22 AG
ED153	N	N	N	Lock washer is against the lug on both terminals / Line screw is golden colored	N	N	N		N	N	N	N	Dirty			W480-487-10 / W484-106-22 AG
ED154	N	N	N	Lock washer is against the lug on both terminals	N	N	N		N	N	N	N	Dirty			W480-550-10 / W484-276-22 AF
ED155	N	N	N	Lock washer is against the load lug only	N	N	N	2 lugs on load terminal	N	N	N	N	Dirty			W480-482-10, W480-481-10 / W484-791-22 C, W484-785-22 AF
EE191	N	N	N	Lock washer against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-416-14 AJ, W480-403-14 AJ / W484-131-20 AH
EE156	N	N	N	asher against bot	N	N	N		N	N	N	N	Dirty			W480-196-12 / W484-169-22 AF
EE157	N	N	N	asher against bot	N	N	N	2 wires in load lug	N	N	N	N	Dirty			W480-330-10 / W484-111-22 AF, W484-108-22 AF
EE158	N	N	N	Lock washer against load lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-304-8, W480-338-8 / W484-119-22 AH
EH184	N	N	N		N	N	Y	Lock washers on both lugs, 2 wires in load lug	N	N	N	N	Dirty			W484-043-18 AF/w480-409-10W480-408-10
EH159	N	N	N	Lock washer against load lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-394-8, W480-407-10 / W484-039-18 AF
EH160	N	N	N	Lock washer against load lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-407-10, W480-408-10 / W484-041-18 AF

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	2	E	H	161	Gen No. 1 / DC / Control	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	Very Dusty
2	2	F	D	162	Flight Controls / T/O and Cabin Pressure Aural Warn	B-3	BACC1 8U-3	1	0569A	Closed	White	N	N	Y	N	Very Dusty
2	1	F	E	188	Flight Controls / Stabilizer Control / Cruise Control	B-5	BACC1 8U-5	1	1173A	Closed	White	N	N	Y	N	
2	1	F	E	190	Hyd Sys / Pmp Cntrl / Sys B #2	B-5	BACC1 8U-5	1	1173A	Closed	White	N	N	Y	N	
2	2	F	E	163	Flight Controls / Leading Edge Valve	B-5	BACC1 8U-5	1	1173A	Closed	White	N	N	Y	N	
2	2	F	E	164	Hydraulic System/ Low Press Lights / Sys B / Pump No. 2	B-5	B ACC18 U-5	1	1173A	Closed	White	N	N	Y	N	
2	1	F	H	189	APU / Cntl Bus	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	
2	2	F	H	165	APU / Fire Det.	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	
2	1	G	B	199	Windshear / DC1	B-1	BAC-C18U-1	1	1087A	Closed	White	N	N	N	N	
2	2	G	B	166	Stall Warning / Fail Btry	B-1	BACC1 8U-1	1	0569A	Closed	White	N	N	N	N	
2	2	G	B	167	Interphone / Dual Power Source / Serv & Att	B-1	BACC1 8U-1	1	0968A	Closed	White	N	N	N	N	
2	2	G	B	168	Interphone / Dual Power Source / Flt & E/R	B-1	BACC1 8U-1	1	0769A	Closed	White	N	N	N	N	
2	2	G	B	169	Interphone / Dual Power Source / F/O & OBS	B-1	BACC1 8U-1	1	0569A	Closed	White	N	N	N	N	
2	2	G	B	170	Interphone / Dual Power Source / Capt & 3rd C/M	B-1	BACC1 8U-1	1	0769A	Closed	White	N	N	N	N	
2	1	G	D	198	Mach Warning	B-3	BAC-C18U-3	1	0369A	Open	White	N	N	Dusty	N	
2	2	G	D	171	Voice RCDR	C-3	BACC1 8Z3R	1	9242	Closed	Green	N	N	N	N	Line Term. Black in color
2	2	G	D	172	Mach Warn -1	B-3	BACC1 8U-3	1	0369A	Closed	White	N	N	Y	N	Yellow cap on button, Slightly Dirty
2	2	G	D	173	Passenger Accomodations / Water Qty Ind	B-3	BACC1 8U-3	1	0569A	Closed	White	N	N	Y	N	Slightly Dirty
2	1	G	E	200	Stall Warning / DC	G-5	BAC-C18R5B	1	7349	Closed	White	N	N	Dirty	N	

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
EH161	N	N	N	Lock washer against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-418-14, W480-405-16 / W484-231-18 AF
FD162	N	N	N	2 lugs on load terminal / lockwasher on load terminal	N	N	N	2 wires in both load lugs	N	N	N	N	Dirty			W480-353-8, W480-729-10 / W484-186-20 AM, W484-143-20 AM, W484-27R-22, W484-27D-22
FE188	N	N	N		N	N	N		N	N	N	N	Dirty			W480-367-10,W98-002-20
FE190	N	N	N	Lock washer against load lug	N	N	N	2 lugs on load side / 2 wires in lug on line	N	N	N	N	Dirty			W480-363-10,W480-370-10,W484-181-22 AM,W480-813-22
FE163	N	N	N	Lock washer against load lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-300-10, W480-379-10 / W484-207-20 AI
FE164	N	N	N	Lock washer against both lugs	N	N	N		N	N	N	N	Dirty			W480-342-10 / W484-113-20 AL
FH189	N	N	N		N	N	N	2Wires in each lug	N	N	N	N	Dirty			W480-506-14,W480-508-16,W484-570-18 Y,W484-188-18 AM
FH165	N	N	N	Lock washers against both lugs	N	N	N	2 wires in each lug	N	N	N	N	Dirty			W480-508-16, W480-509-16 / W484-554-18 AL, W484-589-18 Y
GB199	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W033-9019-20,W033-164-22
GB166	N	N	N	Lock washers against both lugs / Lock washer broken	N	N	N		N	N	N	N	Dirty			W33-077-16 / W33-720-22 K
GB167	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-140-22 AC, W33-141-22 AA / W033-164-22
GB168	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-140-22 AC, W33-139-22 AC / W33-702-22 D
GB169	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-139-22 AC, W33-138-22 AC / W33-597-22 D
GB170	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-138-22 AC, W33-137-22 AA / W33-596-22 D
GD198	N	N	N	Lock washers against both terminals	N	N	N	2 wires in line lug	N	N	N	N				W33-073-16,W33-069-16,W33-571-22 AA
GD171	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-143-16 / W33-704-22 D
GD172	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Slightly Dirty			W33-074-16, W33-075-16 / W33-198-22 F
GD173	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Slightly Dirty			W508-058-8, W508-041-10 / W508-152-20
GE200	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			WW33-075-16,W33-066-16/W33-721-22

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	2	G	E	174	Passenger Accommodations / Oxygen Ind & Valve	G-5	BAC-C18R5B	1	7349	Closed	White	N	N	Y	N	Slightly Dirty
2	2	G	E	175	Passenger Accommodations / Galley Cont	G-5	BAC-C18R5B	1	7349	Closed	White	N	N	Y	N	Slightly Dirty
2	2	G	E	176	Windshear / 115 AC	B-5	BACC18U-5	1	0987A	Closed	White	N	N	N	N	Yellow cap on button, Terminals black in color
2	2	G	E	177	Stall Warning / AC	R-5	BAC-C18R-5B	1	0369	Closed	White	N	N	Y	N	Slightly Dirty
2	2	G	E	178	Pass Address / Ampl Btry	R-5	BAC-C18R-5B	1	0160	Closed	White	N	N	Y	N	Slightly Dirty
2	2	G	H	179	Passenger Accommodations / Service Outlet / Aft	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	Slightly Dirty / Terminals have black speckles
2	1	H	D	213	Window Heat/Right #2/AC Control	B-3	BAC-C18U-3	1	0569A	Open	White	N	N	Dirty/ Dusty	N	Yellow cap on button
2	2	H	D	181	Window Heat / Left No. 1 / DC Control	N-3	BACC18Z 3R	1	9014	Closed	Black	N	N	N	N	Terminals have black speckles
2	2	H	D	182	Window Heat / Right No. 1 / AC Control	C-3	BACC18Z3R	1	7851, 1278	Closed	Gray	N	N	N	N	Green dot on body above 1278 date code / Line terminal black
2	2	H	D	183	Miscellaneous A.C. / Equipment Cooling / Warning Lt.	B-3	BACC18U-3	1	0569A	Closed	White	N	N	Y	N	Very dusty
2	1	H	E	217	Anti-ice and rain/Heaters/Pitot/Right	B-5	BAC-C18U-5	1	1173A	Closed	White	N	N	Dirty/ Dusty	N	
2	2	H	E	180	Anti-Ice and Rain / Pitot Heater/ Off Light	C-5	BACC18Z5R	1	7922	Closed	Gray	N	N	Y	N	Green dot on body on same side as CAGE Code / Very dusty
2	2	H	E	185	Window Heat / Right 4-5	B-5	BACC18U5	1	1173A	Closed	White	N	N	Y	N	Very Dusty
2	2	H	F	201	Miscellaneous A.C. / Equipment Cooling / Blower	D-7.5	B.A.C.10-60806-7	A	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	201	Miscellaneous A.C. / Equipment Cooling / Blower	D-7.5	B.A.C.10-60806-7	B	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	201	Miscellaneous A.C. / Equipment Cooling / Blower	D-7.5	B.A.C.10-60806-7	C	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	204	Miscellaneous A.C. / Battery Charger	D-7	B.A.C.10-60806-7	A	0275A	Closed	Red	N	N	Y	N	Very Dusty / Copper dust on breaker body
2	2	H	F	204	Miscellaneous A.C. / Battery Charger	D-7	B.A.C.10-60806-7	B	0275A	Closed	Red	N	N	Y	N	Very Dusty / Copper dust on breaker body

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
GE174	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Slightly Dirty			W508-059-10 / W508-154-20
GE175	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Slightly Dirty			W508-074-10, W508-041-10 / W508-139-16
GE176	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Line wire transluscent gray in color			W033-9018-20 / W33-553-22
GE177	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-076-16, W33-722-22 K
GE178	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-146-16, W33-077-16 / W33-703-22 D
GH179	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-077-12, W508-079-12 / W508-581-16
HD213	N	N	N		N	N	N	Lock washers against both lugs/2 wires in line lug	N	N	N	N	Dirty			W480-193-12,W480-169-12 AA/WW484-724-22 AB
HD181	N	N	N	Lock washers against both lugs / Lock washer under load lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-362-10, W480-19A-10 / W484-014-22 AA
HD182	Y	N	Maybe	Lock washers against both lugs / Screw inserted crossthreadded	N	N	N		N	N	N	N	Dirty		HD181V2, HD182V2, HD182V3	W480-156-12 AA / W484-010-22 AA
HD183	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W480-285-10 / W484-234-22 AB
HE217	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W484-065-20 AA/W480-188-12
HE180	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Kapton / SS 92607			W480-19A-10 / No marking on load wire
HE185	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-224-12 AA / W480-736-12 AA / W484-007-20 AA
HF201	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-233-14 AB / W484-235-18 AB
HF201	N	N	N	Lock washers against all lugs	N	N	N	Load lock washer broken	N	N	N	N	Dirty			W480-234-14 AB / W484-236-18 AB
HF201	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-235-14 AB / W484-237-18 AB
HF204	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-248-12 AB, W480-245-10 / W484-301-20 AB
HF204	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-249-12 AB, W480-246-10 / W484-302-20 AB

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	2	H	F	204	Miscellaneous A.C. / Battery Charger	D-7	B.A.C.1 0-60806-7	C	0275A	Closed	Red	N	N	Y	N	Very Dusty / Copper dust on breaker body
2	2	H	F	207	Miscellaneous A.C. / No. 1 TR. Unit	D-7.5	B.A.C.1 0-60806-7	A	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	2	H	F	207	Miscellaneous A.C. / No. 1 TR. Unit	D-7.5	B.A.C.1 0-60806-7	B	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	2	H	F	207	Miscellaneous A.C. / No. 1 TR. Unit	D-7.5	B.A.C.1 0-60806-7	C	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	2	H	F	210	Miscellaneous A.C. / No.2 TR. Unit	D-7.5	B.A.C.1 0-60806-7	A	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	210	Miscellaneous A.C. / No.2 TR. Unit	D-7.5	B.A.C.1 0-60806-7	B	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	210	Miscellaneous A.C. / No.2 TR. Unit	D-7.5	B.A.C.1 0-60806-7	C	1173A	Closed	Red	N	N	Y	N	Very Dusty / Yellow cap on button
2	2	H	F	214	Miscellaneous A.C. / Essential TR. Unit	D-7.5	B.A.C.1 0-60806-7	A	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	2	H	F	214	Miscellaneous A.C. / Essential TR. Unit	D-7.5	B.A.C.1 0-60806-7	B	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	2	H	F	214	Miscellaneous A.C. / Essential TR. Unit	D-7.5	B.A.C.1 0-60806-7	C	1173A	Closed	Red	N	N	Y	N	Very Dusty
2	1	H	H	221	Anti-ice and rain/Wipers/Left	B-10	BACC1 8U10	1	0873A	Open	White	N	N	Dirty	N	
2	2	H	H	186	Miscellaneous A.C. / 28V Transformers / Instrument / No.1	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Dirty	N	
2	2	H	H	187	Miscellaneous A.C. / Atr Compt Heaters / Ph. B	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Dirty	N	Both terminals partially black
2	2	H	H	193	Anti-Ice and Rain / Wipers / Right	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Dirty	N	Both terminals partially black
2	2	H	I	194	Miscellaneous A.C. / 28V Transformers / Main / No. 1	P-15	BAC-C18R-15B	1	0773	Closed	White	N	N	Dirty	N	Both terminals partially black / Both terminals are loose
2	2	H	I	195	Miscellaneous A.C. / 28V Transformers / Main / No. 3	P-15	BAC-C18R-15B	1	0873	Closed	White	N	N	Y	N	Both terminals partially black / Both terminals are loose

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
HF204	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-250-12 AB, W480-247-10 / W484-303-20 AB
HF207	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-170-14 / W484-295-16 AA
HF207	N	N	N	Lock washers against both lugs / Load lock washer broken	N	N	N		N	N	N	N	Dirty			W480-171-14 AA / W484-296-16 AA
HF207	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-172-14 AA / W484-297-16 AA
HF210	N	N	N	Lock washers against all lugs / Flat washer against terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-190-10, W480-187-12 AA / W484-298-16 AA
HF210	N	N	N	Lock washers against all lugs / Flat washer against terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-191-10, W480-188-12 AA / W484-299-16 AA
HF210	N	N	N	Lock washers against all lugs / Flat washer against terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-192-10, W480189-12 AA / W484-300-16 AA
HF214	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N		N	N	N	N	Dirty			W480-261-10 / W484-304-16 AB
HF214	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-262-10, W480-252-10 / W484-305-16 AB
HF214	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N		N	N	N	N	Dirty			W480-263-10 / W484-306-16 AB
HH221	N	N	N		N	N	N	Lock washers against both lugs/2 wires on line lug	N	N	N	N	Dirty			W480-354-10,W480-350-6/W484-067-18 AB
HH186	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-288-8, W480-285-10 / W480-289-18
HH187	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-736-12 AA / W484-736-16 AA
HH193	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-302-8, W480-423-10 / W484-068-18 AB
HI194	N	N	N	Lock washers against all lugs / Flat washer against line terminal	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-158-12 AA, W480-159-10 / W480-451-14
HI195	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W480-162-12 AB / W480-453-14

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	1	I	B	230	Autopilot/Engage Intlk	B-1	BACC1 8U-1	1	1168A	Closed	White	N	N	Y	N	Yellow cap on button
2	1	I	B	231	STBY Horiz Inv	K-1		1	9043	Closed	Blue	N	N	N	N	
2	1	I	B	232	Comparator Monitor Navigation / VHS	B-1	BACC1 8U1	1	9128	Closed	White	N	N	N	N	
2	2	I	B	198	NAV-1 / VOR Loc / Stby Pwr	B-1	BACC1 8U-1	1	0769A	Closed	White	N	N	N	N	
2	2	I	B	197	Navigation /VHS NAV-2 / GS	B-1	BACC1 8U-1	1	0569A	Closed	White	N	N	N	N	
2	2	I	B	218	Communications / SELCAL-1	B-1	BACC1 8U-1	1	0968A	Closed	White	N	N	N	N	Load clinch nut broke loose from terminal
2	2	I	B	219	Capt's Inst / Stby Pwr / Comp-1	B-1	BACC1 8U-1	1	0269A	Closed	White	N	N	N	N	
2	2	I	B	220	Capt's Inst / Stby Pwr / Horiz	B-1	BACC1 8U-1	1	0269A	Closed	White	N	N	N	N	
2	2	I	B	222	F/O's Inst / Horiz	B-1	BACC1 8U-1	1	0768A	Closed	White	N	N	N	N	
2	2	I	B	223	F/O's Inst / Comp-2	B-1	BACC1 8U-1	1	0269A	Closed	White	N	N	N	N	
2	2	I	B	224	R/T MON / CAPT	B-1	BACC1 8U-1	1	0469A	Closed	White	N	N	N	N	
2	2	I	B	225	R/T MON / F/O	B-1	BACC1 8U-1	1	0968A	Closed	White	N	N	N	N	
2	2	I	B	226	FLT DIR-1	B-1	BACC1 8U-1	1	0768A	Closed	White	N	N	N	N	Yellow cap on button
2	2	I	B	227	FLT DIR-2	B-1	BACC1 8U-1	1	768	Closed	White	N	N	N	N	Yellow cap on button
2	1	I	D	237	Navigation/DME-1/AC	B-3	BACC1 8U-3	1	0569A	Closed	White	N	N	Dirty/ Dusty	N	
2	2	I	D	228	DME-2 / DC	B-3	BACC1 8U-3	1	0569A	Closed	White	N	N	N	N	
2	2	I	E	229	TCAS CMPTR	B-5	BACC1 8U-5	1	9103	Closed	White	N	N	N	N	Looks new, Red cap on button
2	2	I	E	236	Autopilot / Roll / AC	B-5	BACC1 8U-5	1	1173A	Closed	White	N	N	N	N	Yellow cap on button
2	2	I	E	238	Yaw Damper / Upper Rudder / DC	B-5	BACC1 8U-5	1	1173A	Open	White	N	N	Y	N	Dirty
2	2	I	F	233	A/P & Cruise Stab Trim Actuator 3 Phase	E-7.5	BACC1 8W7	A	9302	Closed	Black	N	N	Y	N	Yellow cap on button
2	2	I	F	233	A/P & Cruise Stab Trim Actuator 3 Phase	E-7.5	BACC1 8W7	B	9302	Closed	Black	N	N	Y	N	Yellow cap on button
2	2	I	F	233	A/P & Cruise Stab Trim Actuator 3 Phase	E-7.5	BACC1 8W7	C	9302	Closed	Black	N	N	Y	N	Yellow cap on button
2	2	I	H	239	Communications / VHF - 2	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	Terminals are partially black
2	2	J	B	240	Lighting / Control Cabin / Background Lights / Lamp Tester	B-1	BACC1 8U-1	1	0269A	Closed	White	N	N	Y	N	

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
IB230	N	N	N		N	N	N	Lock washers against both lugs/2 wires on line lug	N	N	N	N	Dirty			W33-101-16,W33-008-16/W33-507-22 E
IB231	N	N	N		N	N	N	Lock washers against both lugs	N	N	N	N	Dirty			W33-098-20/W33-197-22 F
IB232	N	N	N		N	N	N	Lock washers on both lugs/2 wires on load lug	N	N	N	N	Dirty			W33-015-16,W33-091-16/W33-186-22 E
IB196	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-133-16, W33-134-16 / W33-430-22 G
IB197	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-055-16, W33-056-16 / W33-184-22 E
IB218	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-029-16, W33-037-16 / W33-719-22 D
IB219	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-022-20, W33-023-20 / W33-158-22 E
IB220	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-058-20, W33-021-20 / W33-160-22 E
IB222	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-101-16, W33-102-16 / W33-525-22 G
IB223	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-099-16, W33-100-16 / W33-522-22 G
IB224	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W33-016-16 / W33-177-22 E
IB225	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Dirty			W33-085-16 / W33-535-22 G
IB226	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-011-16, W33-019-16 / W33-174-22 E
IB227	N	N	N	Lock washers against all lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-095-16, W33-103-16 / W33-530-22 G
ID237	N	N	N		N	N	N	Lock washers against both lugs	N	N	N	N	Dirty			W33-732-22 C/W33-047-16
ID228	N	N	N	2 lugs on load terminal / lockwasher against lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty, One clean and looks new			W33-125-16, W33-126-16 / W33-575-22 G, W9035-9001-20
IE229	N	N	N	Lock washers against all lugs	N	N	N		N	N	N	N	Clean, look new			W033-9021-20 / W033-9024-20
IE236	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-004-16, W33-006-16 / W33-511-22 F
IE238	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-081-16, W33-094-16 / W33-548-22 J
IF233	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-015-16, W33-011-16 / W33-501-22 F
IF233	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-014-16 / W33-502-22 F
IF233	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-013-16 / W33-502-22 F
IH239	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W33-111-16, W33-110-16 / W33-562-16
JB240	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-083-12 / W508-199-20

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	1	J	D	244	Lighting/ Panels & Instruments/ Radio Primary	J-3	BACC1 8R-3A	1	7333	Closed	Blue	N	N	Y	N	
2	1	J	D	245	Lighting/Control Cabin/Dome White	B-3	BACC1 8U3	1	0673A	Closed	White	N	N	Y	N	
2	2	J	D	241	Lighting / Control Cabin / OBS Read	J-3	BAC-C18R-3A	1	7333	Closed	Blue	N	N	Y	N	
2	2	J	D	242	Lighting / Control Cabin / Flt. Engr Table	J-3	BAC-C18R-3A	1	7333	Closed	Blue	N	N	Y	N	
2	2	J	D	243	Lighting / Control Cabin / Control Stand	J-3	BAC-C18R-3A	1	7333	Closed	Blue	N	N	Y	N	
2	2	J	D	246	Lighting / Control Cabin / Background Lights / Pilots	J-3	BAC-C18R-3A	1	7333	Closed	Blue	N	N	Y	N	
2	2	J	D	247	Lights / Exterior Lights / Left / FWD & Side / Sec	C-3	BACC1 8Z3R	1	8828	Closed	Gray	N	N	Y	Y	Green dot on side of body
2	2	J	D	248	Lights / Exterior Lights / Left / FWD & Side / Prim	J-3	BAC-C18R-3A	1	Jan-69	Closed	Blue	N	N	Y	N	Terminals are partially black / Missing wafer board
2	1	J	E	253	Lighting/ Indicator Lights/ Master Dimming Bus/ No.1 DC	B-5	BACC1 8U5	1	1268A	Closed	White	N	N	Y	N	
2	2	J	E	249	Exterior Lights / Navigation / Standby	B-5	BACC1 8U-5	1	1068A	Closed	White	N	N	Y	N	
2	1	J	H	255	Lighting/ Runway Turnoff/ Right	G-10	BACC1 8R10B	1	8045	Closed	White	N	N	Y	N	
2	2	J	H	250	Lighting / Exterior Lights / Wing Illum	B-10	BACC1 8U10	1	0373A	Closed	White	N	N	Y	N	
2	2	J	H	251	Lighting / Panels & Instruments / Flight Engr	B-10	BACC1 8U10	1	0373A	Closed	White	N	N	Y	N	
2	1	K	D	258	Passenger Cabin Lighting/Airstair Entry/Bright	B-3	BACC1 8U3	1	1083A	Closed	White	N	N	N	N	
2	1	K	D	259	Passenger Cabin Lighting/ Galley Fluor	B-3	BACC1 8U3	1	0369A	Closed	White	N	N	Y	N	
2	2	K	D	252	Passenger Cabin Lighting / Emergency Exit / Bat Chg / 115V AC	B-3	BACC1 8U-3	1	0369A	Closed	White	N	N	Y	N	
2	1	K	E	262	Service/Nose Wheel Well	G-5	BACC1 8R5B	1	7350	Closed	White	N	N	N	N	Dusty
2	2	K	E	254	Passenger Cabin Lighting / Service / Air Cond Compt	G-5	BACC1 8R5B	1	7348	Closed	White	N	N	Y	N	Line terminal is slightly black

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
JD244	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/1 wire per lug	N	N	N	N	Dirty			W508-115-20/W508-015-12 AH
JD245	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/1 wire per lug	N	N	N	N	Dirty			W508-030-14/W508-131-20
JD241	N	N	N	Lock washers against both lugs / Line clinch nut has white oxidation	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-004-12 AG, W508-530-12 / W508-104-20
JD242	N	N	N	Lock washers against both lugs / Line clinch nut has white oxidation	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-004-12 AG, W508-501-12 AG / W508-101-20
JD243	N	N	N	Lock washers against both lugs / Line clinch nut has white oxidation	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-501-12 AG, W508-005-12 AG / W508-102-20
JD246	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-542-12 / W508-541-20
JD247	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	Y	Dirty		JD247V1, JD247V2	W508-080-18, W508-638-18 / W508-099-18
JD248	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-018-12 AH, W508-020-10 / W508-120-18
JE253	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/1 wire per lug	N	N	N	N	Dirty			W508-619-22/W508-002-10
JE249	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-026-12 / W508-108-18
JH255	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in line lug	N	N	N	N	Dirty			W508-072-10,W508-016-8/W508-127-18
JH250	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-024-12 / W508-125-18
JH251	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-072-10, W508-017-10 / W508-117-18
KD258	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in both lugs	N	N	N	N	Dirty			W508-089-12,W508-023-12/W508-509-22,W508-510-22
KD259	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in load lug	N	N	N	N	Dirty			W508-190-20,W508-559-20/W508-083-12
KD252	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-095-12 / W508-192-20
KE262	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in line lug	N	N	N	N				W508-022-10,W508-007-10/W508-107-20
KE254	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-021-12, W508-006-12 / W508-106-20

Panel Info		Circuit Breaker Information								Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	2	K	E	256	Passenger Cabin Lighting / Lavatory / Dome	G-5	BACC18R5B	1	7348	Closed	White	N	N	Y	N	Yellow cap on button / Black speckles on load terminal
2	1	K	H	265	Passenger Cabin Lighting/ Right Reading Station/1120	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	Dusty
2	1	K	H	266	Passenger Cabin Lighting/ Left Reading Station/1120	B-10	BACC18U10	1	0973A	Closed	White	N	N	Y	N	Dusty
2	2	K	H	257	Passenger Cabin Lighting / Right Reading Station / 950C - 940	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	
2	2	K	H	260	Passenger Cabin Lighting / Right Reading Station / 830 - 720E	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	Line terminal is slightly black
2	2	K	H	261	Passenger Cabin Lighting / Right Reading Station / 700 - 580	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	
2	2	K	H	263	Passenger Lighting / Ceiling / Power / L. Aft	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	Yellow cap on button / Black speckles on line terminal
2	2	K	H	264	Passenger Lighting / Ceiling / Power / R. Aft	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	Yellow cap on button / Black speckles on line terminal
2	2	K	H	267	Passenger Lighting / Ceiling / Power / Fwd	B-10	BACC18U10	1	0973A	Closed	White	N	N	Y	N	Yellow cap on button / Black speckles on line terminal
2	2	K	H	268	Passenger Cabin Lighting / Left Reading Station / 980 - 950C	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	
2	2	K	H	269	Passenger Cabin Lighting / Left Reading Station / 940 - 830	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	
2	2	K	H	271	Passenger Cabin Lighting / Left Reading Station / 720E - 700	B-10	BACC18U10	1	0373A	Closed	White	N	N	Y	N	
2	2	K	H	272	Passenger Cabin Lighting / Service / Main Wheel Well	B-10	BACC18U10	1	0973A	Closed	White	N	N	Y	N	
2	2	K	I	273	Passenger Cabin Lighting / Service / Cargo Compt / Aft	R-15	BAC-C18R-15B	1	0873	Closed	White	N	N	Y	N	Both terminals are loose
2	2	K	I	274	Passenger Cabin Lighting / Service / Cargo Compt / Fwd	R-15	BAC-C18R-15B	1	0873	Closed	White	N	N	Y	N	Both terminals are loose and have black speckles
2	2	K	I	275	Passenger Cabin Lighting / Ceiling / Window	R-15	BAC-C18R-15B	1	0873	Closed	White	N	N	Y	N	Yellow cap on button / Both terminals are loose and have black speckles
2	1	L	B	270	Fuel System/ Warning Lights/ Ind Temp	B-1	BACC18U1	1	0569A	Closed	White	N	N	Y	N	Very Dirty
2	2	L	B	276	Fuel System / Qty	B-1	BACC18U-1	1	0569A	Closed	White	N	N	Y	N	Very Dirty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
KE256	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-031-14 / W508-187-22
KH265	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in line lug	N	N	N	N	Dirty			W508-163-12 AC,W508-176-12/WW508-196-16
KH266	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/1 wire per lug	N	N	N	N	Dirty			W508-522-12/W508-172-16
KH257	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-159-10, W508-084-10 / W508-186-16
KH260	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-328-10, W508-088-10 / W508-184-16
KH261	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-086-10, W508-527-12 / W508-182-18
KH263	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-051-10, W508-081-10 / W508-451-16
KH264	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-095-12, W508-062-10 / W508-454-18
KH267	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-052-10 / W508-455-18
KH268	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W508-163-12 AC / W508-171-16
KH269	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-522-12 AC, W508-073-12 AC / W508-169-16
KH271	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-084-10, W508-185-10 / W508-167-18
KH272	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-032-12, W508-008-10 / W508-122-18
KI273	N	N	N	Lock washers against both lugs	N	N	N	2 wires in load lug	N	N	N	N	Dirty			W508-032-12 / W508-655-16, W508-133-16
KI274	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-023-10, W508-637-12 / W508-134-16
KI275	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-033-12 , W508-081-10 / W508-040-16
LB270	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/1 wire per lug	N	N	N	N	Very Dirty			W480-291-18/W484-084-22 AC
LB276	N	N	N	Lock washers against both lugs / 2 wires on load terminal	N	N	N		N	N	N	N	Very Dirty			W480-272-10 / W484-901-20, W484-117-22 AC

Panel Info		Circuit Breaker Information								Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	1	L	D	279	Air Conditioning System/ Auto AC	B-3	BACC1 8U3	1	0569A	Closed	White	N	N	Y	N	Very Dusty
2	2	L	D	277	Air Conditioning System / Auto Pack Trip	C-3	BACC1 8Z3R	1	8842	Closed	White	N	N	Y	N	Very Dusty / Load terminal is black
2	1	L	E	281	Air Conditioning System/ Zone Temperature/ Control	B-5	BACC1 8U5	1	1173A	Closed	White	N	N	Y	N	Very Dirty/Button Edges Broken
2	1	L	E	282	Air Conditioning System/ Zone Temperature/ Overheat	B-5	BACC1 8U5	1	1173A	Open	White	N	N	Y	N	Very Dirty
2	2	L	F	283	Air Conditioning System / Gasper Fan	D-7.5	B.A.C.1 0-60806-7	A	1173A	Closed	Red	N	N	Y	N	Very Dirty / Phase B load washer broke
2	2	L	F	283	Air Conditioning System / Gasper Fan	D-7.5	B.A.C.1 0-60806-7	B	1173A	Closed	Red	N	N	Y	N	Very Dirty / Phase B load washer broke
2	2	L	F	283	Air Conditioning System / Gasper Fan	D-7.5	B.A.C.1 0-60806-7	C	1173A	Closed	Red	N	N	Y	N	Very Dirty / Phase B load washer broke
2	2	L	G	288	Fuel System / Tank No. 2 / Fwd Left Boost Pump	E-8		A	1273A	Closed	White	N	N	Y	N	Very Dirty
2	2	L	G	288	Fuel System / Tank No. 2 / Fwd Left Boost Pump	E-8		B	1273A	Closed	White	N	N	Y	N	Very Dirty
2	2	L	G	288	Fuel System / Tank No. 2 / Fwd Left Boost Pump	E-8		C	1273A	Closed	White	N	N	Y	N	Very Dirty
2	2	L	G	291	Fuel System / Tank No. 2 / Aft Right Boost Pump	E-8		A	0389A	Closed	White	N	N	Y	N	Very Dirty / Load terminal is black
2	2	L	G	291	Fuel System / Tank No. 2 / Aft Right Boost Pump	E-8		B	0389A	Closed	White	N	N	Y	N	Load terminal is black
2	2	L	G	291	Fuel System / Tank No. 2 / Aft Right Boost Pump	E-8		C	0389A	Closed	White	N	N	Y	N	Load terminal is black
2	1	L	H	287	Fuel System/Fueling Valves/In-Flight Close	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	Very Dirty
2	2	L	H	278	Bat. Bus / Hot Battery / Bus	B-10	BACC1 8U10	1	0873A	Closed	White	N	N	Y	N	Very Dirty

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
LD279	N	N	N	Lock washers against both lugs	N	N	N	Lock washers against both lugs/2 wires in line lug	N	N	N	N	Very Dirty			W480-100-14 AE, W480-102-14 AE/W484-720-20 AC
LD277	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-728-16, W480-446-16 / W484-725-20 AD
LE281	N	N	N	Lock washers against both lugs	N	N	N	Lock washers on both lugs/Flat washer on line terminal/2 wires in line lug	N	N	N	N	Very Dirty			W480-080-12,W480-087-12/W484-056-20 AF
LE282	N	N	N	Lock washers against both lugs	N	N	N	Lock washers on both lugs/Flat washer on line terminal/2 wires in line lug	N	N	N	N	Very Dirty			W480-366-10,W480-331-10/W484-057-22 AF
LF283	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-433-12, W480-242-12 / W484-029-20 AE
LF283	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-432-14 AD, W480-243-12 / W484-030-20 AE
LF283	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-432-14 AD, W480-244-12 / W484-031-20 AE
LG288	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Very Dirty			W480-269-10 / W484-151-18 AD
LG288	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Very Dirty			W480-281-10 / W484-152-18 AD
LG288	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-272-10, W480-273-10 / W484-153-18 AD
LG291	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-151-8, W480-269-10 / W484-154-18 AE
LG291	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-152-8, W480-281-10 / W484155-18 AE
LG291	N	N	N	Lock washers against both lugs / Flat washer on line lug	N	N	N	2 wires in line lug	N	N	N	N	Very Dirty			W480-153-8, W480-271-10 / W484-156-18 AE
LH287	N	N	N	Lock washers against both lugs	N	N	N	Lock washers on both lugs/2 wires in load lug	N	N	N	N	Dirty			W480-901-10/W484-903-18,W484-120-18
LH278	N	N	N	Lock washers against both lugs / Flat washer on line terminal / 2 lugs on line terminal	N	N	N		N	N	N	N	Dirty			W480-585-8 / W484-703-18 AG / No marking on second line wire

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
2	2	L	J	280	Miscellaneous D.C. / Battery / Transfer Bus	G-20	BAC-C18R20 B	1	7341	Closed	White	N	N	Y	N	Very Dirty
2	2	L	J	286	Miscellaneous D.C. / Essential / Radio Bus	G-20	BAC-C18R20 B	1	7349	Closed	White	N	N	Y	N	Very Dirty
2	2	L	J	294	Miscellaneous D.C. / Standby Ess DC	G-20	BAC-C18R20 B	1	7343	Closed	White	N	N	Y	N	Very Dirty
2	2	L	J	295	Bat. Bus / Gen Control / DC Bus	G-20	BAC-C18R20 B	1	7338	Closed	White	N	N	Y	N	Very Dirty
2	2	L	K	296	Miscellaneous D.C. / Battery / Bus Supply	S-50	BAC-C18R-50C	1	0869	Closed	White	N	N	Y	N	Very Dirty
2	2	L	K	297	Miscellaneous D.C. / Essential / Bus Tie	U-50	BAC-C18X-50	1	8911	Closed	White	N	N	Y	N	Very Dirty
2	2	L	K	298	Miscellaneous D.C. / D.C. Bus / No. 1	S-50	BAC-C18R-50C	1	0869	Closed	White	N	N	Y	N	Very Dirty
2	2	L	K	299	Miscellaneous D.C. / D.C. Bus / No. 2	S-50	BAC-C18R-50C	1	0869	Closed	White	N	N	Y	N	Very Dirty / Both terminals are blackened
2	2	L	K	300	Miscellaneous D.C. / D.C. Bus / Ess	S-50	BAC-C18R-50C	1	0869	Closed	White	N	N	Y	N	Very Dirty / Both terminals are blackened
2	1	G	B	301	Windshear / DC2	B-1	BACC18U-1	1	1185A	Closed	White	N	N	N	N	
2	1	I	B	302	F/O's Inst / Comp-2	B-1	BACC18U-1	1	0569A	Closed	White	N	N	N	N	
1	1	B	D	303	L Emer AC Bus / Compass 1	A-3		1	0374A	Closed	White	N	N	N	N	
1	1	C	D	304	AC Bus 3 / ADF-2	B-3	CC18U-	1	9138	Closed	White	N	N	N	N	Slight residue / Yellow cap
1	1	A	E	305	AC Bus 1 / Misc / Captain Seat Power / Phase C	A-5		1	0874A	Closed	White	N	N	Y	N	
1	1	B	E	306	Battery Direct Bus / Battery Relay	A-5		1	0674A	Closed	White	N	N	N	N	

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
LJ280	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-414-10, W480-373-10 / W480-425-14 AE
LJ286	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-375-8, W480-442-8 / W484-393-12
LJ294	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-500-10, W480-442-8 / W484-578-10
LJ295	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-586-10, W480-588-10 / W480-727-14 AD
LK296	N	N	N	Lock washers against both lugs / Flat washer under both lugs	N	N	N		N	N	N	N	Dirty			W480-371-6 / W480-427-8
LK297	Y	N	N	Lock washers against both lugs / Flat washer under both lugs / Load screw loose	N	N	N		N	N	N	N	Dirty			W480-303-6 / W480-424-6
LK298	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N		N	N	N	N	Dirty			W480-611-6 / W480-614-10
LK299	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N		N	N	N	N	Dirty			W480-612-6 / W480-615-10
LK300	N	N	N	Lock washers against both lugs / Flat washer under line lug	N	N	N		N	N	N	N	Dirty			W480-613-6 / W480-616-10
GB301	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W033-9820-20 / W033-188-22
IB302	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W33-039-16 / W33-523-22 G
BD303	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N		N	N	N	N	Dirty			1F12948-300, X326A10 / 1F1A24
CD304	N	N	N	Lock washers against both lubs	N	N	N		N	N	N	N	Dirty			B7-43, 2X411A16 / 2RD31C22
AE305	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N		N	N	N	N	Dirty			CCC, 1X230C8C1 / M13C24C
BE306	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N		N	N	N	N	Dirty			B7-52, P4A6 / P10A20

Panel Info	Circuit Breaker Information									Circuit Breaker Visual Inspection						
A/C	P1 or P2	Sample Number			Panel Notation for Breaker	Mfr. Code	Boeing Spec No.	Phases	Date Code	Breaker Description		Breaker Condition				
		Panel #	Current Rating	Specimen Number						Open/ Closed?	Body Color	Corroded ?	Cracked ?	Dirty ?	Indication of High Temp?	Other Visual Comments
1	1	D	E	307	DC Bus 3 / Ice & Rain / Eng Anti-Ice Valve / Eng 3	A-5		1	0874A	Open	White	N	N	Y	N	Very Dirty
1	1	B	H	308	Left Emer DC Bus / Emer Lights / Standby	A-10		1	0674A	Closed	White	N	N	Y	N	
1	1	D	H	309	AC Bus 1 / Air Conditioning / Avionics Compartment Fan / Phase B	A-10		1	0974A	Closed	White	N	N	N	N	Evidence of spillage
2	1	E	D	310	Landing Gear / Indication / Lever Latch / Lights	B-3	BACC18U-3	1	0569A	Closed	White	N	N	Y	N	Very Dirty
2	1	J	D	311	Lighting / Overhead / 28 V / Sec	B-3	BACC18U-3	1	0973A	Closed	White	N	N	Y	N	
2	1	E	E	312	Engine No. 3 / Fuel De-Ice	B-5	BACC18U-5	1	1173A	Closed	White	N	N	Y	N	Yellow Cap
2	1	L	E	313	Fuel System / Warning Lights / Pump Low Press	B-5	BACC18U-5	1	1173A	Closed	White	N	N	Y	N	Very Dirty
2	1	J	H	314	Lighting / Exterior Lights / Taxi	B-10	BACC18U10	1	1273A	Closed	White	N	N	Y	N	
2	1	K	H	315	Passenger Cabin Lighting / Left Reading Station / 580 - 460	B-10	BACC18U10	1	0973A	Closed	White	N	N	Y	N	
2	2	L	J	316	Miscellaneous D.C. / Standby / Bat	G-20	BAC-C18R20B	1	7314	Closed	White	N	N	Y	N	Very Dusty / Black residue on load terminal

	Circuit Breaker Visual Inspection															
	Terminal Screw Condition				Terminal Lug Condition				Wire Condition					Comments	Sample Photo	Circuit ID Number
Sample Number	Loose ?	Corroded ?	Damage Thread?	Other Visual comments	Poor Crimp ?	Sharp Bends ?	Corroded ?	Other Visual Comments	Corroded ?	Split Insulation ?	Discoloration?	High Temp Expos?	Other Visual Comments			
DE307	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N		N	N	N	N				B7-30, P178B8 / 3H1059C16
BH308	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N	2 lugs on load	N	N	N	N	Dirty			B7-45, P8C10 / L2701D18, L2701C20
DH309	N	N	N	Inspector's lacquer / Flat washers on both lugs	N	N	N		N	N	N	N	Dirty			BBB, 1X229D8B / H108B20B
ED310	N	N	N	Lock washers against both lugs	N	N	N	4 wires in load lug	N	N	N	N	Dirty			W480-336-16, W480-438-16 / W484-093-22 AG, W484-094-22 AG, W484-095-22 AG, W484-107-22 AG
JD311	N	N	Y	Lock washers against both lugs / Load screw cross threaded	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-835-16, W508-0520-16 / W508-116-20
EE312	N	N	N	Flat washer on line terminal only / Brass screw on load terminal only	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W480-229-12 AD, W480-232-12 / W484-104-20 AG
LE313	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W480-286-12 AD / W484-128-22 AC
JH314	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-001-8, W508-027-10 / W508-505-18
KH315	N	N	N	Lock washers against both lugs	N	N	N	2 wires in line lug	N	N	N	N	Dirty			W508-525-8, W508-526-10 / W508-165-18
LJ316	N	N	N	Lock washers against both lugs	N	N	N		N	N	N	N	Dirty			W480-351-10 / W484-577-10

APPENDIX C—CIRCUIT BREAKER PERFORMANCE REQUIREMENTS

FAA CIRCUIT BREAKER MANUFACTURER SAMPLE TEST PARAMETERS

MFR	Mfr part number code (- Amp rating)	Test Process 1 or 2	Min. trip %	Min. trip time (sec)	Max. trip %	Max. trip time (sec)	Percent overload 1	Percent overload 1 time (sec)	Percent overload 2	Percent overload 2 time (sec)	Max. pull-out force (lbs)	Max. reset force (lbs)	Foot notes
TI	A -	1&2	115	3600	145	3600	200	2-20	500	0.16-1.0	5	5	
	B -	1&2	115	3600	145	3600	200	2-20	500	0.16-1.0	5	5	
	C-	2	115	3600	138	3600	200	5-20	500	.5-2.0	5	5	
	D-	2	105	3600	140	3600	200	12-65	400	2.3-1.0	14	23	Note 1
	E-7.5	2	105	3600	145	3600	200	2-20	500	.16-1.0	3	15	Note 1
	E-8	2	115	3600	145	3600	200	6-35	400	.65-1.8	3	15	Note 1
MP	G -	1	115	3600	138	3600	200	15-55	600	1-3.5	2*-8	4*12	* Note 2
	H -	1/2	115	3600	138	3600	200	15-55	N/A	N/A	8	12	Note 3
	I -	1/2	115	3600	138	3600	200	15-55	N/A	N/A	8	12	Note 3
	J -	1	110	3600	138	3600	200	0.3-1.8	600	.045-0.2	2*-8	4*-12	* Note 2
	K -	1	115	3600	145	3600	200	2-20	500	0.16-2.0	5	5	
	L -	1	115	3600	138	300	150	1-8	N/A	N/A	8	6	
	M -	2	105	3600	145	3600	200	10-70	400	2-15	12	16	
	N -	2	115	3600	138	3600	200	5-20	500	0.5-2	1.5*-5	1*-5	*Note 2 Note 8,
	U-	2	115	3600	138	3600	200	30-65	400	3-9	.35*-12	2*-16	*Note 2
WE	P - 15	2	115	3600	138	3600	200	15-55	600	1-3.5	8	12	Note 4
	P - 20	2	115	3600	138	3600	200	15-55	600	1-3.5	8	12	Note 4
	P - 5	2	115	3600	138	3600	200	15-55	600	1-3.5	2-8	4-12	Note 5
	R - 15	2	115	3600	138	3600	200	15-55	600	1-3.5	2-8	4-12	Note 6
	S - 50	2	115	3600	138	3600	200	30-65	600	1-3.5	2-8	4-16	Note 7

Note 1: 105% each phase 145% on one phase and 100% on two phases
Note 2: Minimum pull out force
Note 3: 700-30- and 700-066 are the same circuit breaker. Dual marking may occur.
Note 4: Similar to thr MS25244-
Note 5: Similar to the BACC18R5B
Note 6: Similar to the BACC18R15B
Note 7: Similar to the BACC18R50C
Note 8: Similar to the BACC18X50

APPENDIX D—FAA CIRCUIT BREAKER TEST PROCEDURE

D.1 LVCR ALTERNATIVE.

LOW VOLTAGE CONTACT RESISTANCE TEST METHOD ALTERNATIVE

The Low Voltage Contact Resistance (LVCR) test method is specified in blocks 5, 11, and 16 of Process 1 and blocks 19, 21, 31, 47b, 54b, 58b, and 64 of Process 2. The LVCR method requires a Direct Current (DC) resistive load of 200 Milli-amps at 26 +/- 2 volts in series with a switch and the Circuit Breaker (CB) being tested.

A constant current across the CB is essential to provide comparable LVCR results from breaker to breaker. To maintain constant current in the DC resistive load circuit described above, Raytheon Technical Service Company (RTSC) expected to make continuous adjustments in the circuit resistor or the driving voltage as the resistive elements in the circuit changed. RTSC would by necessity have to constantly monitor and record the current. To eliminate this variable, RTSC choose to use a constant current power supply method rather than a resistive load method to generate a constant 200 Milli-amps. The open circuit 26 Volts DC was maintained.

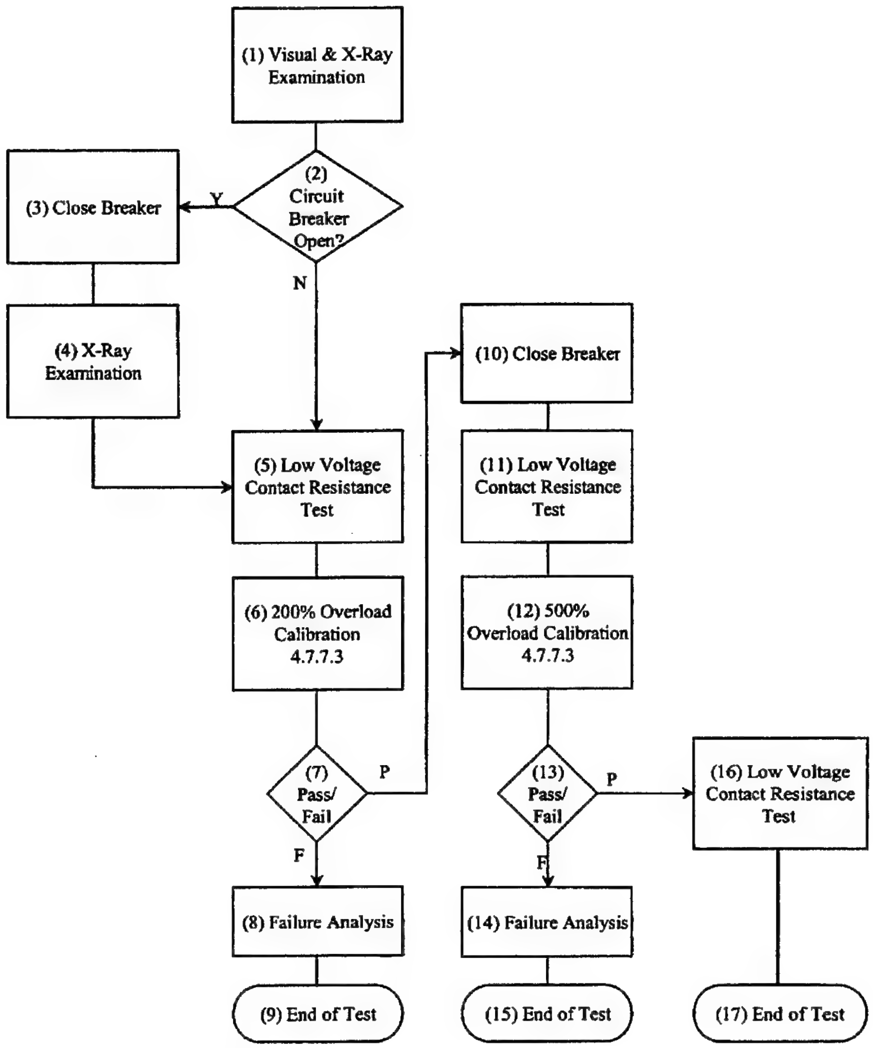
Ohm's Law states that a voltage drop across a resistance is equal to the current flowing though the resistor, in this case the CB, multiplied by the resistance of that resistor. The open circuit voltage, in this case 26 Volts DC, does not affect this law. The required driving voltage only ensures that a constant current, in this case 200 Milli-amps, is maintained. Ohm's law demonstrates that a constant current power supply approach provides the same result as a resistive load circuit approach.

However, RTSC noted during the switching operation that current surges were occurring when the switch closed the circuit. The surges were caused by the power supply adjusting, at the high 26 Volt value, for the changes in circuit resistance. Although the surges did not seem to cause any significant changes in the various LVCR values across the CB, which might occur due to a temperature rise, it will cause a low amp rated breaker to open.

Typically the driving voltage for LVCR tests are maintained at low values to prevent current surges that may cause temperature rises that do affect the LVCR value. To prevent the current surges in the CB, RTSC recommends the open circuit voltage be maintained at one Volt, not 26 Volts.

It is RTSC's technical opinion that the constant current power supply LVCR test method at one Volt yields the same result as the resistive load method at 26 Volts, minimizes the number of circuit variables that may be required to be controlled, and reduces the time required to perform the test.

D.2 PROCESS 1 TEST PLAN.



TEST PROCESS NUMBER 1 FLOWCHART BLOCK DEFINITIONS

The chart above contains the Test Process Number 1 Flowchart. The flowchart illustrates the sequence of tests to be performed on the breakers designated for test. Each block in the flowchart is numbered. Complete descriptions of each block are provided below. To avoid repetition, blocks containing the same process are grouped together.

Block 1: **Visual & X-Ray Examination**

MIL-C-5809 Test Number: NA

Special Instructions: Each circuit breaker shall be examined visually and radiographically to record the initial condition of the breaker. Each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 2: **Circuit Breaker Open (Y/N)**

MIL-C-5809 Test Number: NA

Special Instructions: Record the state of the circuit breaker as either OPEN or CLOSED. If OPEN proceed to block 3. If CLOSED proceed to block 5. Do not change the state of the breaker.

Block 3, 10: **Close Breaker**

MIL-C-5809 Test Number:

Special Instructions: Breaker shall only be closed once. DO NOT cycle the breaker.

Block 4: **X-Ray Examination**

MIL-C-5809 Test Number:

Special Instructions: Generally, each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 5, 11, 16: **Low Voltage Contact Resistance Test**

MIL-C-5809 Test Number: 4.7.17.1 (see special instructions)

Special Instructions: 4.7.17.1 is normally performed in conjunction with Moisture Resistance tests (4.7.17). Moisture resistance is not part of this evaluation. However, the low voltage contact resistance measurement procedures described in 4.7.17.1 will be followed with the following deviations. Each CB will be operated in a circuit containing a dc resistive load of 200 milliamps at 26 ±2 volts. In series with the load shall be a manually operated switch (not the CB) to control power on/off. The contact resistance (specified as millivolt drop) shall be computed by averaging the result of 10 measurements. Each measurement shall be taken after a consecutive switch closure. All measurements shall be made across the CB external electrical

terminals. (Note: The circuit breaker shall not be exercised on/off during this test) Soak (no load) at ambient for one-hour minimum before test.

Block 6: **200% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 200% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 7: **Pass/fail (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 8: **Failure Analysis (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 6 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 55 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 12: **500% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 500% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 13: **Pass/fail (500% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 14: **Failure Analysis (500% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

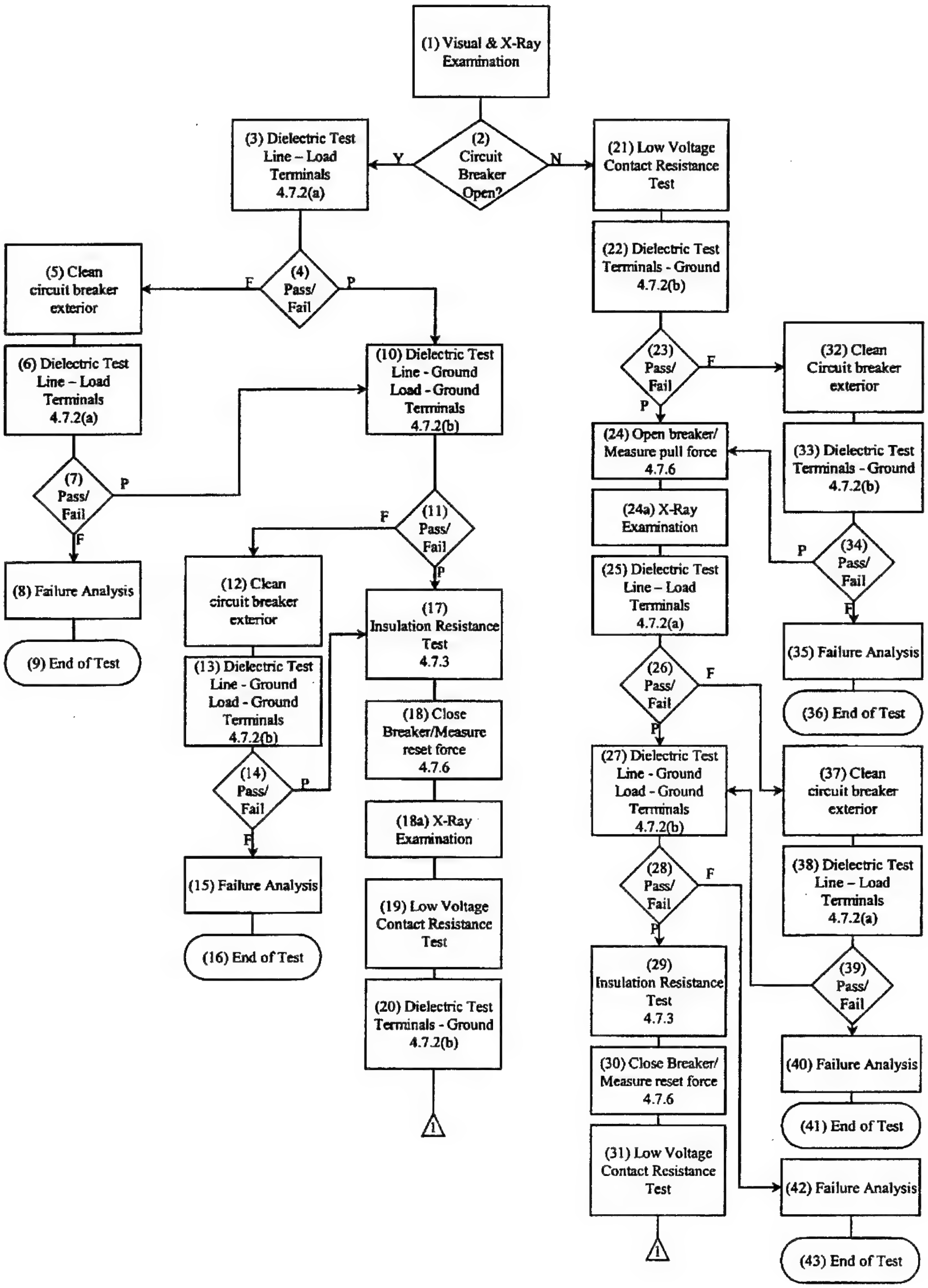
Special Instructions: As the first step in the failure analysis, the OEM will repeat test 59 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 59 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

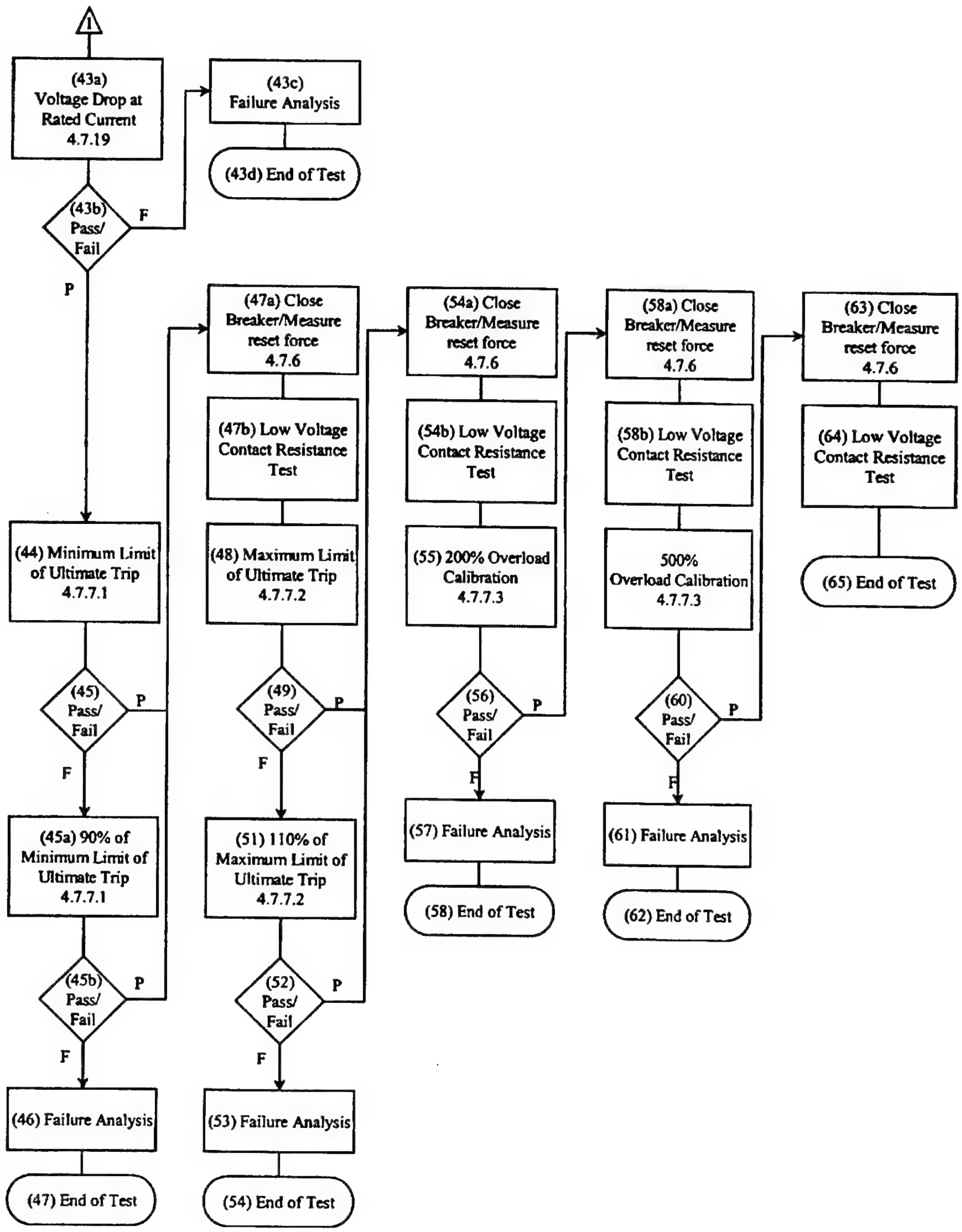
Block 17: **End of Test**

MIL-C-5809 Test Number: NA

Special Instructions: Safely store the CB in a suitable container that will protect the CB from physical or chemical damage. Insure that the breaker is properly labeled. Store the CB in its end of test state. Do not close or open the CB switch, or manipulate the CB in any way. If the circuit breaker has been disassembled, collect and properly store all remaining parts.

D.3 PROCESS 2 TEST PLAN.




1
(43a) Voltage Drop at Rated Current 4.7.19
(43b) Pass/ Fail
F
P
(43c) Failure Analysis
(43d) End of Test
(44) Minimum Limit of Ultimate Trip 4.7.7.1
(45) Pass/ Fail
P
F
(45a) 90% of Minimum Limit of Ultimate Trip 4.7.7.1
(45b) Pass/ Fail
P
F
(46) Failure Analysis
(47) End of Test
(47a) Close Breaker/Measure reset force 4.7.6
(47b) Low Voltage Contact Resistance Test
(48) Maximum Limit of Ultimate Trip 4.7.7.2
(49) Pass/ Fail
P
F
(51) 110% of Maximum Limit of Ultimate Trip 4.7.7.2
(52) Pass/ Fail
P
F
(53) Failure Analysis
(54) End of Test
(54a) Close Breaker/Measure reset force 4.7.6
(54b) Low Voltage Contact Resistance Test
(55) 200% Overload Calibration 4.7.7.3
(56) Pass/ Fail
P
F
(57) Failure Analysis
(58) End of Test
(58a) Close Breaker/Measure reset force 4.7.6
(58b) Low Voltage Contact Resistance Test
500% Overload Calibration 4.7.7.3
(60) Pass/ Fail
P
F
(61) Failure Analysis
(62) End of Test
(63) Close Breaker/Measure reset force 4.7.6
(64) Low Voltage Contact Resistance Test
(65) End of Test

TEST PROCESS NUMBER 2 FLOWCHART BLOCK DEFINITIONS

The chart above contains the Test Process Number 2 Flowchart. The flowchart illustrates the sequence of tests to be performed on the breakers designated for test. Each block in the flowchart is numbered. Complete descriptions of each block are provided below. To avoid repetition, blocks containing the same process are grouped together.

Block 1: **Visual & X-Ray Examination**

MIL-C-5809 Test Number: NA

Special Instructions: Each circuit breaker shall be examined visually and radiographically to record the initial condition of the breaker. Each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 2: **Circuit Breaker Open (Y/N)**

MIL-C-5809 Test Number: NA

Special Instructions: Record the state of the circuit breaker as either OPEN or CLOSED. If OPEN proceed to block 3. If CLOSED proceed to block 21. Do not change the state of the breaker.

Block 3, 6, 25, 38: **Dielectric Withstanding Voltage, Line - Load Terminals**

MIL-C-5809 Test Number: 4.7.2(a)

Special Instructions: None.

Block 4, 7, 11, 14, 23, 26, 28, 34, 39: **Pass/Fail**

MIL-C-5809 Test Number: NA

Special Instructions: Pass/Fail criteria specified in MIL-C-5809 paragraph 4.7.2.

Block 5, 12, 32, 37: **Clean CB Exterior**

MIL-C-5809 Test Number: NA

Special Instructions: Gently clean the exterior of the CB, removing any light contamination that may be present. Cleaning shall be performed with a clean, soft, nylon brush; and a clean, soft, cotton rag. Under no circumstances shall cleaning solutions or other materials be used. If the contamination is not removed using the prescribed method, do not attempt further cleaning. Proceed to the next step as prescribed in the process flow chart. If any unusual contamination is present record the characteristics and collect a sample of the contaminants in a specimen bag and proceed to the next step in the test process.

Block 8, 15, 35, 40, 42: **Failure Analysis**

MIL-C-5809 Test Number: NA

Special Instructions: Failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 9, 16, 36, 41, 43, 43d, 47, 54, 58, 62, 65: **End of Test**

`MIL-C-5809 Test Number: NA`

Special Instructions: Safely store the CB in a suitable container that will protect the CB from physical or chemical damage. Insure that the breaker is properly labeled. Store the CB in its end of test state. Do not close or open the CB switch, or manipulate the CB in any way. If the circuit breaker has been disassembled, collect and properly store all remaining parts.

Block 10, 13, 27: **Dielectric Withstanding Voltage; Line - Ground, Load - Ground**

`MIL-C-5809 Test Number: 4.7.2(b)`

Special Instructions: CB shall remain in the open position for these tests. DO NOT close the CB to conduct these tests in the closed position as specified in 4.7.2(b).

Block 17, 29: **Insulation Resistance Test**

`MIL-C-5809 Test Number: 4.7.3`

Special Instructions: Circuit breaker shall remain in the open position. Do not close the breaker when performing this test. Points of measurement shall be specified by the OEM for each CB type and shall be the same as when the CB was qualified.

Block 18, 30, 47a, 54a, 58a, 63: **Close Breaker, Measure reset force**

`MIL-C-5809 Test Number: 4.7.6`

Special Instructions: Breaker shall only be closed once. DO NOT cycle the breaker to get multiple readings.

Block 18a, 24a: **X-Ray Examination**

`MIL-C-5809 Test Number:`

Special Instructions: Generally, each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 19, 21, 31, 47b, 54b, 58b, 64: **Low Voltage Contact Resistance Test**

`MIL-C-5809 Test Number: 4.7.17.1 (see special instructions)`

Special Instructions: 4.7.17.1 is normally performed in conjunction with Moisture Resistance tests (4.7.17). Moisture resistance is not part of this evaluation. However, the low voltage contact resistance measurement procedures described in 4.7.17.1 will be followed with the following deviations. Each CB will be operated in a circuit containing a dc resistive load of 200 milliamps at 26 ±2 volts. In series with the load shall be a manually operated switch (not the CB) to control power on/off. The

contact resistance (specified as millivolt drop) shall be computed by averaging the result of 10 measurements. Each measurement shall be taken after a consecutive switch closure. All measurements shall be made across the CB external electrical terminals. (Note: The circuit breaker shall not be exercised on/off during this test) Soak (no load) at ambient for one-hour minimum before test.

Block 20, 22, 33: **Dielectric Withstanding Voltage; Terminals - Ground**

`MIL-C-5809 Test Number: 4.7.2(b)`

Special Instructions: CB shall remain in the closed position for these tests. Do not open the CB to conduct these tests in the open position as specified in 4.7.2(b).

Block 24: **Open CB, Measure Pull Force**

`MIL-C-5809 Test Number: 4.7.6`

Special Instructions: Breaker shall only be opened once. DO NOT cycle the breaker to get multiple readings.

Block 43a: **Voltage Drop at Rated Current**

`MIL-C-5809 Test Number: 4.7.19.1`

Special Instructions: NA.

Block 43b: **Pass/Fail: Voltage Drop at Rated Current**

`MIL-C-5809 Test Number: 4.7.19.1`

Special Instructions: Pass/Fail criteria specified in MIL-C-5809 paragraph 4.7.19.1.

Block 43c: **Failure Analysis: Voltage Drop at Rated Current**

`MIL-C-5809 Test Number:`

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 43a after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 43a will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 44: **Minimum Limit of Ultimate Trip**

`MIL-C-5809 Test Number: 4.7.7.1`

Special Instructions: Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be

monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 45: **Pass/Fail (Minimum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.1

Special Instructions: The breaker shall not trip and the temperature rise shall not exceed 75°C as specified in 4.7.7.1.

Block 45a: **90% of Minimum Limit of Ultimate Trip**

MIL-C-5809 Test Number: 4.7.7.1
Special Instructions: Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 45b: **Pass/Fail (90% of Minimum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.1

Special Instructions: NA.

Block 46: **Failure Analysis (90% of Minimum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.1

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 45a after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 45a will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 48: **Maximum Limit of Ultimate Trip**

MIL-C-5809 Test Number: 4.7.7.2
Special Instructions: Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 49: **Pass/fail (Maximum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.2

Special Instructions: NA

Block 51: **110% of Maximum Limit of Ultimate Trip**

MIL-C-5809 Test Number: 4.7.7.2
Special Instructions: Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 52: **Pass/fail (110% of Maximum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.2

Special Instructions: NA

Block 53: **Failure Analysis (110% of Maximum Limit of Ultimate Trip)**

MIL-C-5809 Test Number: 4.7.7.2

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 51 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 51 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 55: **200% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 200% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 56: **Pass/fail (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 57: **Failure Analysis (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 55 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after

each of the five-off/on cycles. After the cycling process is complete, test 55 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 59: **500% Overload Calibration**

`MIL-C-5809 Test Number: 4.7.7.3`

Special Instructions: Test at 500% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 60: **Pass/fail (500% Overload Calibration)**

`MIL-C-5809 Test Number: 4.7.7.3`

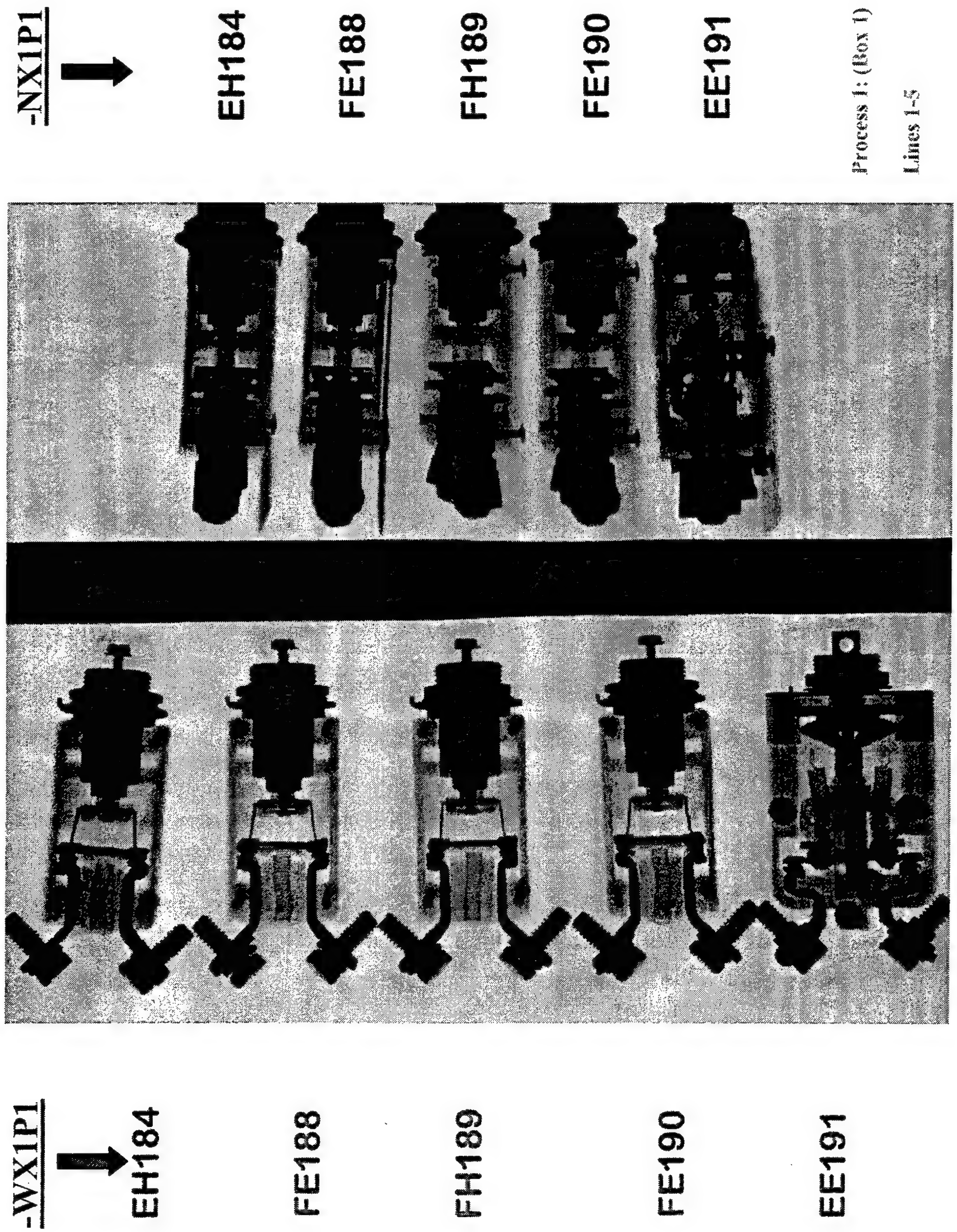
Special Instructions: NA

Block 61: **Failure Analysis (500% Overload Calibration)**

`MIL-C-5809 Test Number: 4.7.7.3`

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 59 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 59 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

APPENDIX E—FAA CIRCUIT BREAKER X-RAYS



-WX1P1

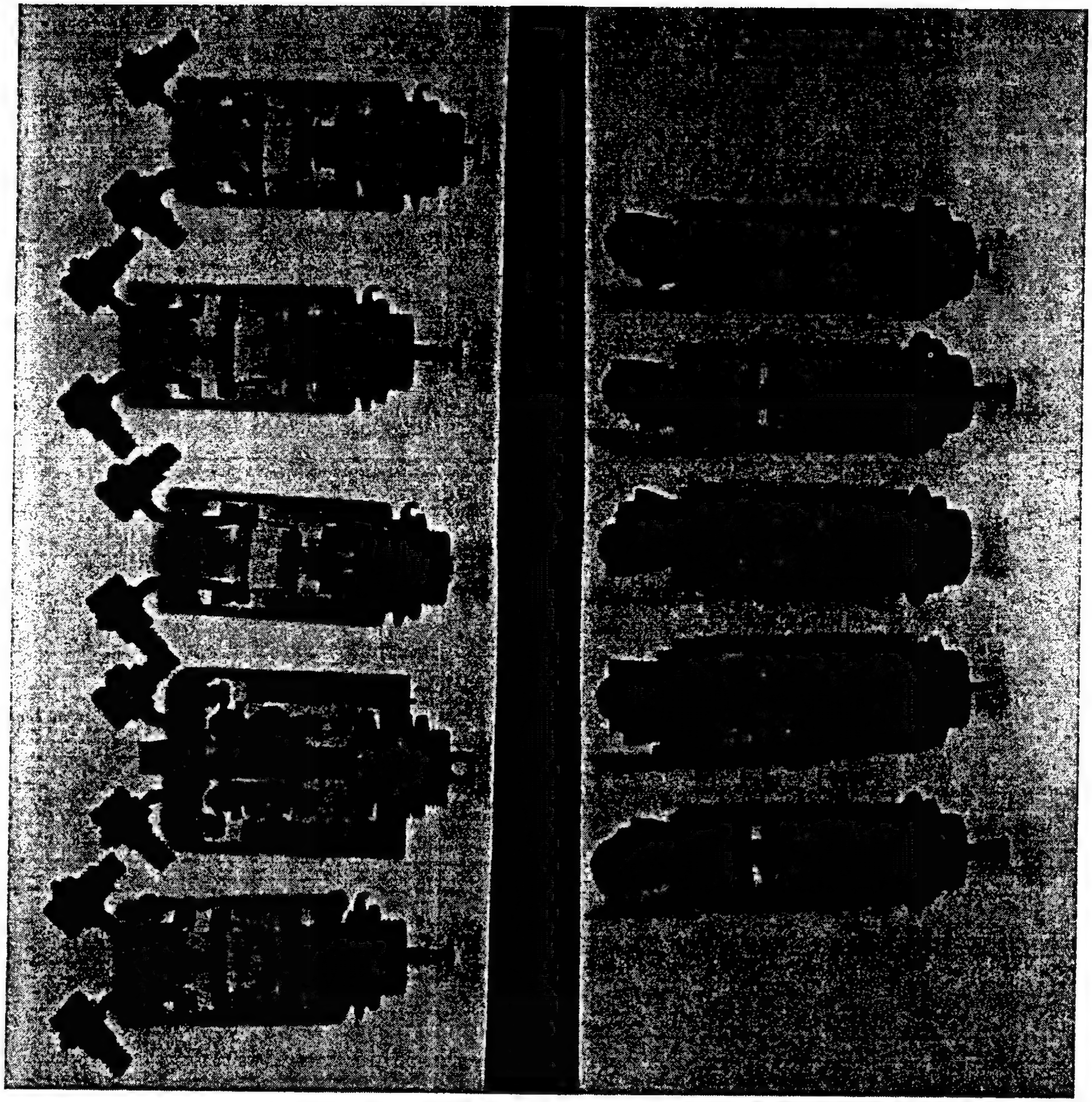
EB192

GD198

GB199

GE200

HD213



-NX1P1

EB192

GD198

GB199

GE200

HD213

Process 1: (Box 1)

Lines 6-10

-WX1P1

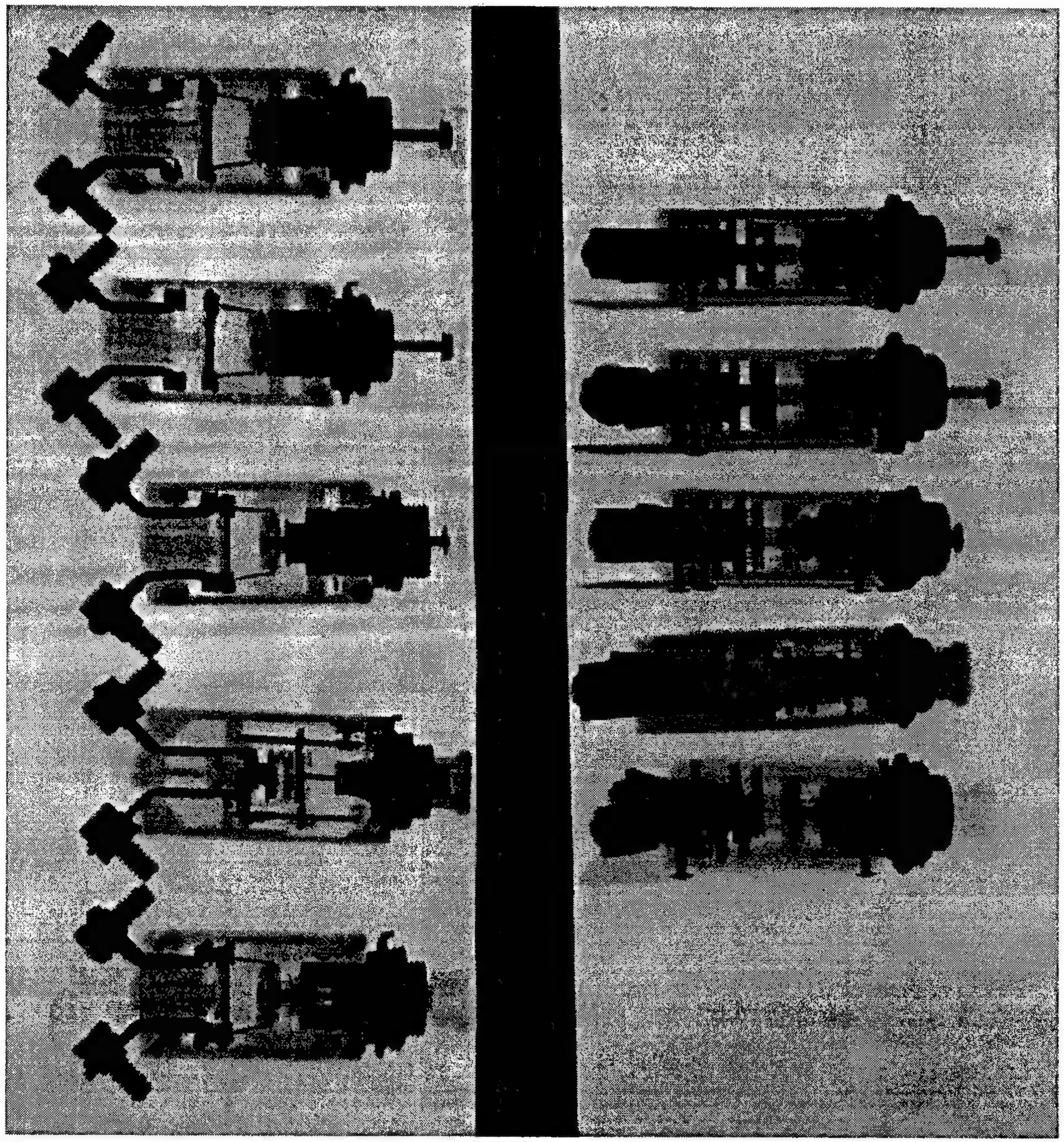
HE217

HH221

IB230

IB231

IB232



-NX1P1

HE217

HH221

IB230

IB231

IB232

Process 1: (Box 1)

Lines 11-15

-WX1P1

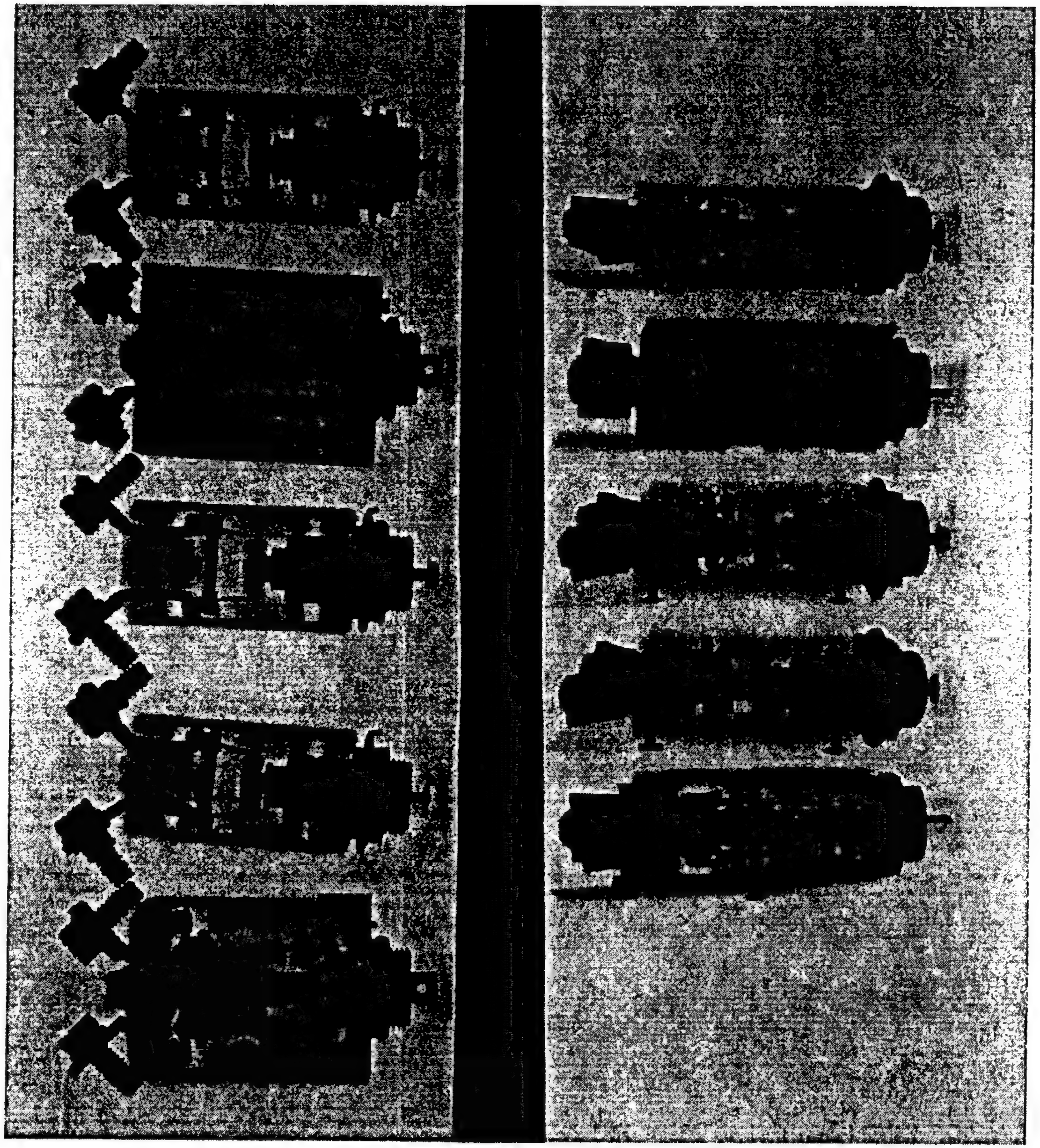
ID237

JD244

JD245

JE253

JH255



-NX1P1

ID237

JD244

JD245

JE253

JH255

Process 1: (Box 1)

Lines 16-20

-WX1P1

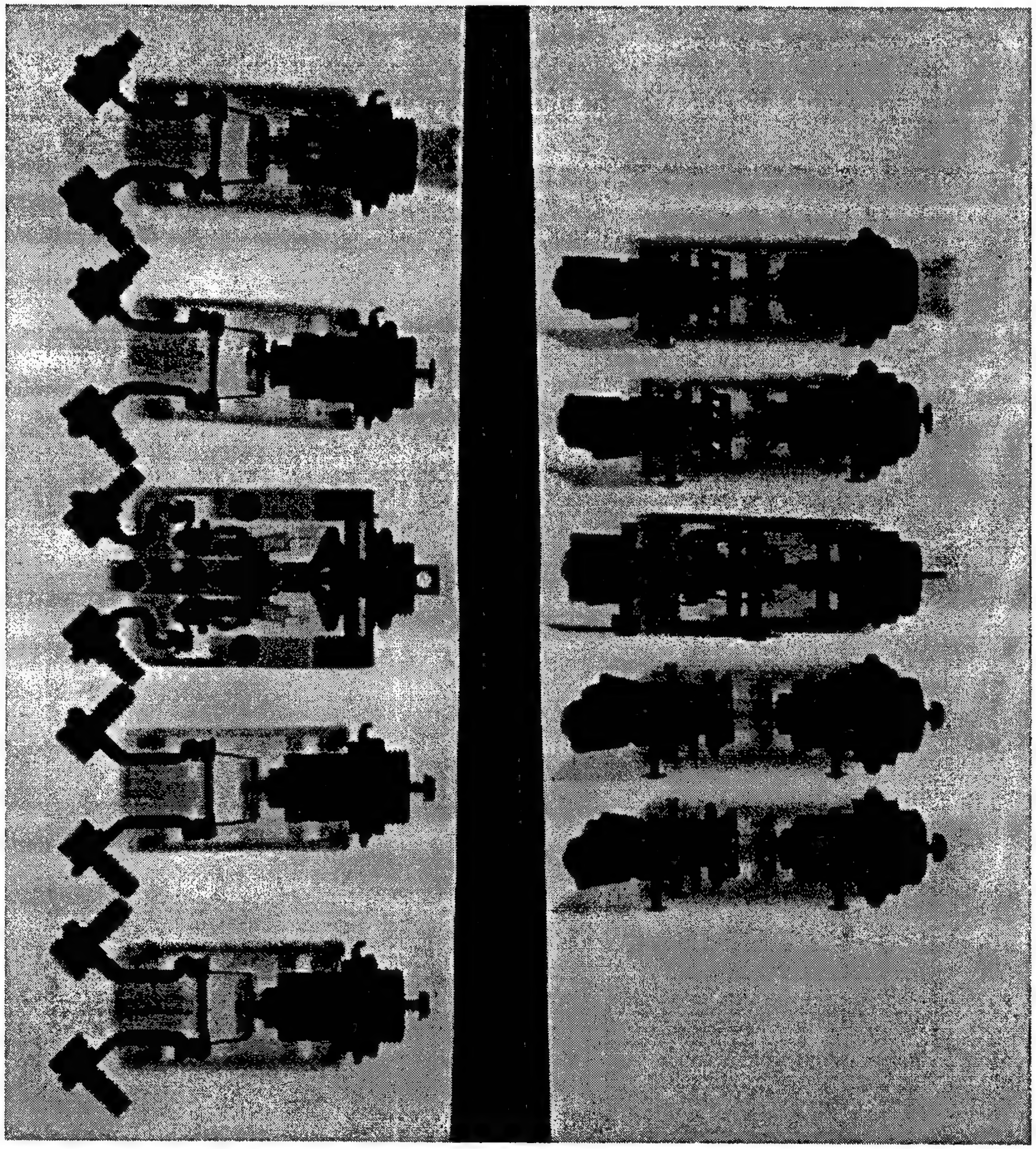
KD258

KD259

KE262

KH265

KH266



-NX1P1

KD258

KD259

KE262

KH265

KH266

Process 1: (Box 1)

Lines 21-25

-WX1P1

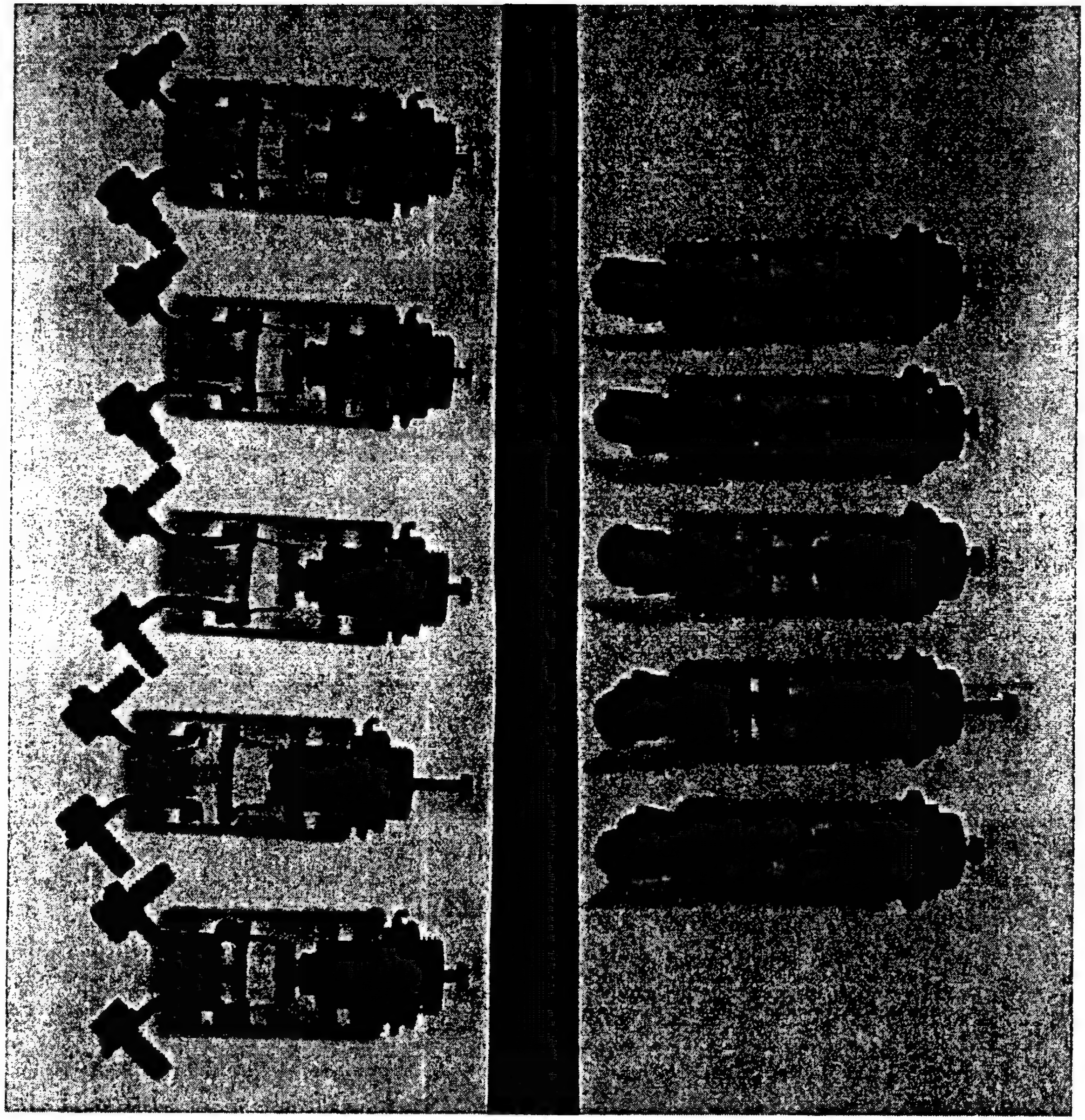
LB277

LD279

LE281

LE282

LH287



-NX1P1

LB277

LD279

LE281

LE282

LH287

Process 1: (Box 1)

Lines 26-30

-WX1P1

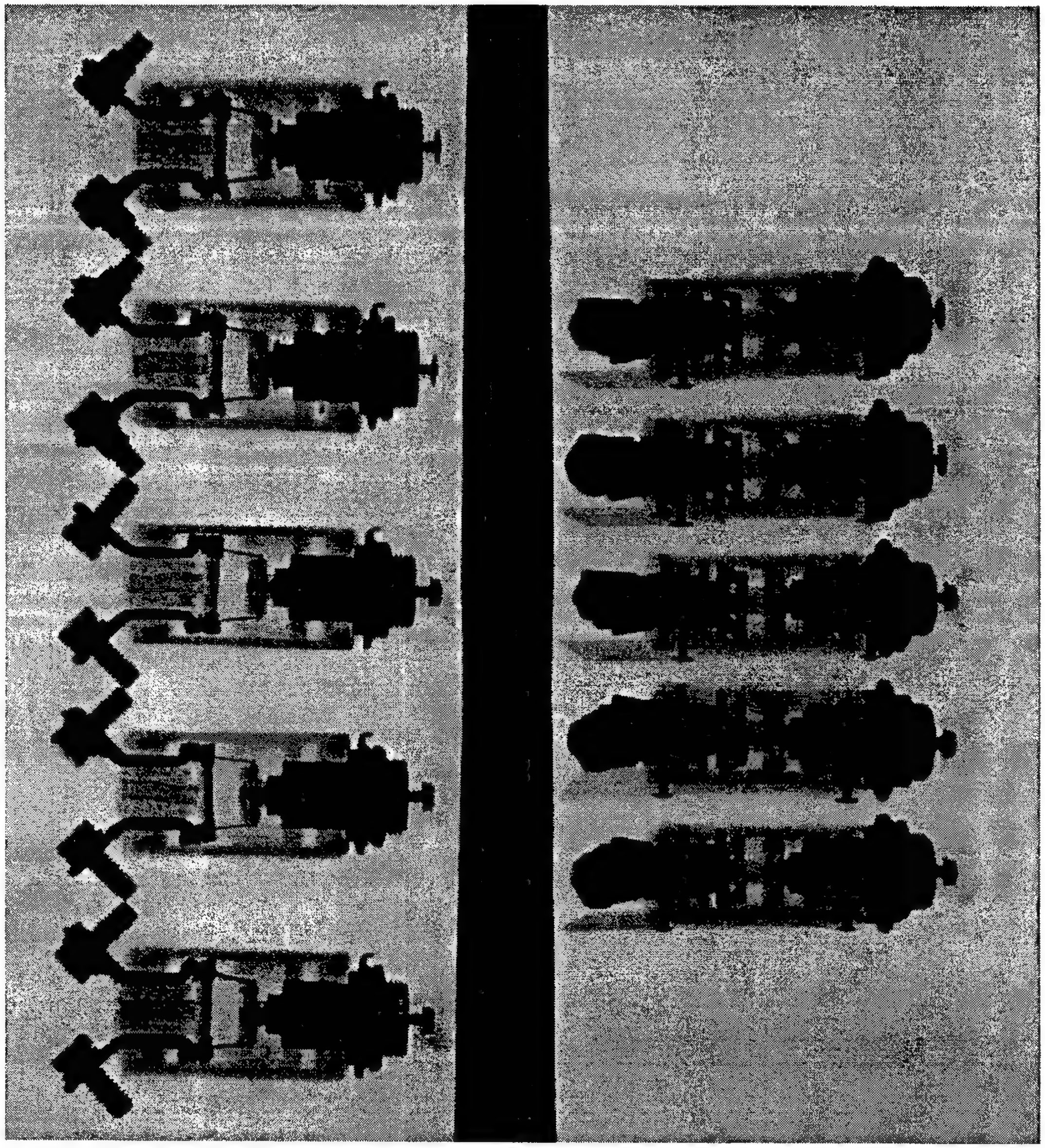
GD198

HD213

HE217

HH221

LE282



-NX1P4

GD198

HD213

HE217

HH221

LE282

Process 1: (Box 4)

Lines 7, 10-12, 29

-WX1P1

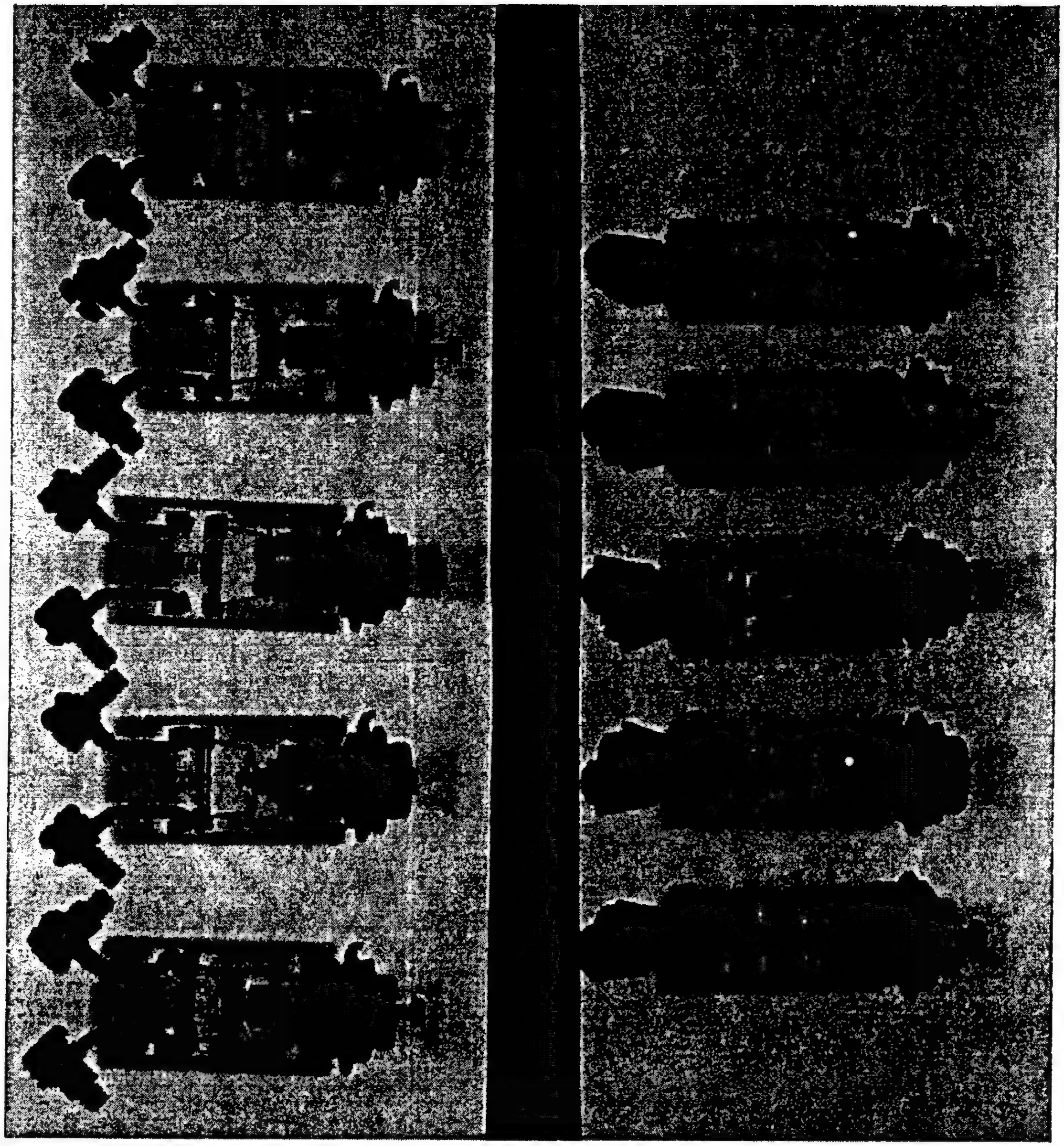
AD001

AD002

AE007

AE008

AH012



-NX1P1

AD001

AD002

AE007

AE008

AH012

Process 1: (Box 1)

Lines 31-35

-WX1P1

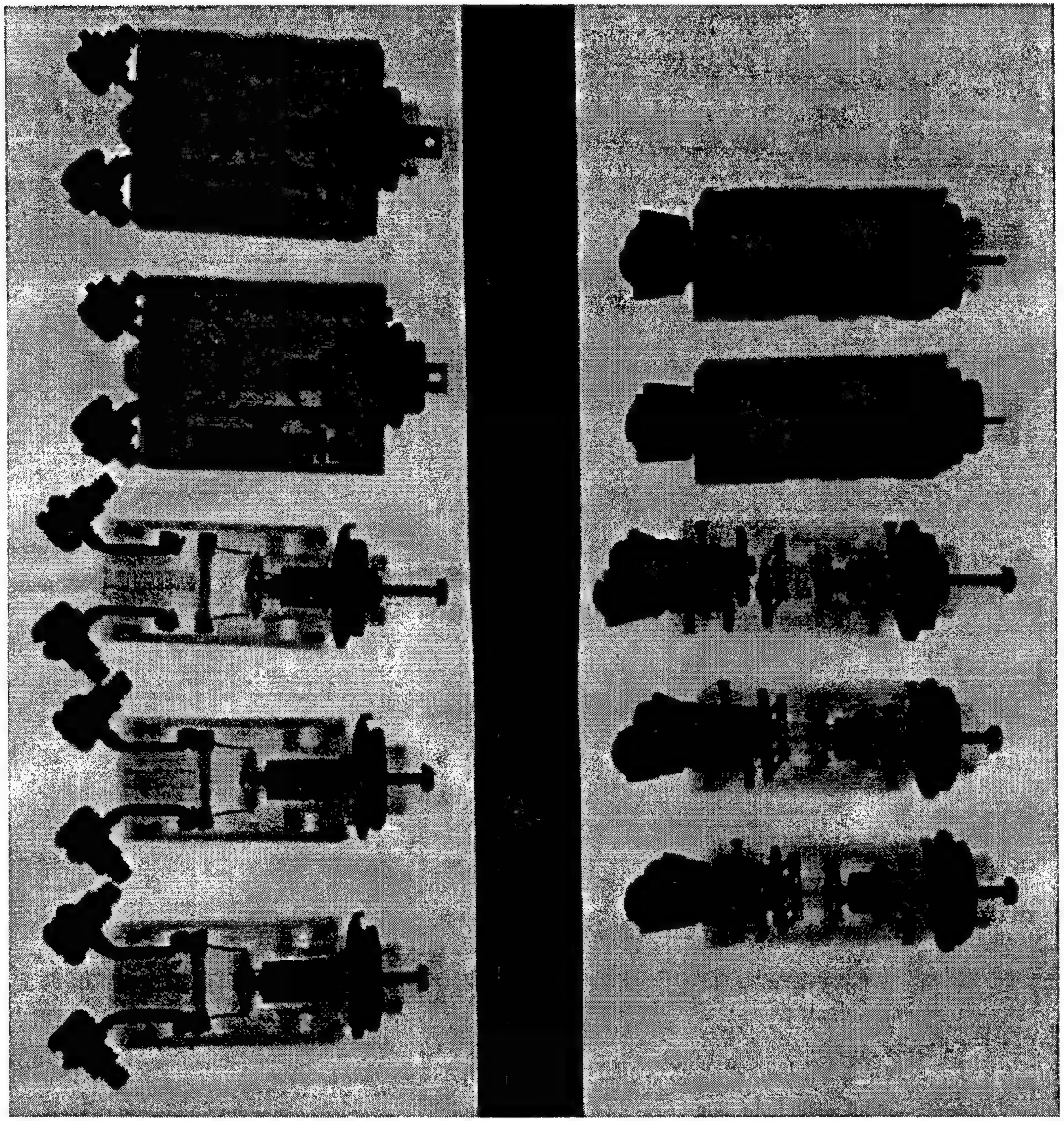
BA020

BA021

BD027

BD028

BD029



-NX1P1

BA020

BA021

BD027

BD028

BD029

Process 1: (Box 1)

Lines 36-40

-WX1P1

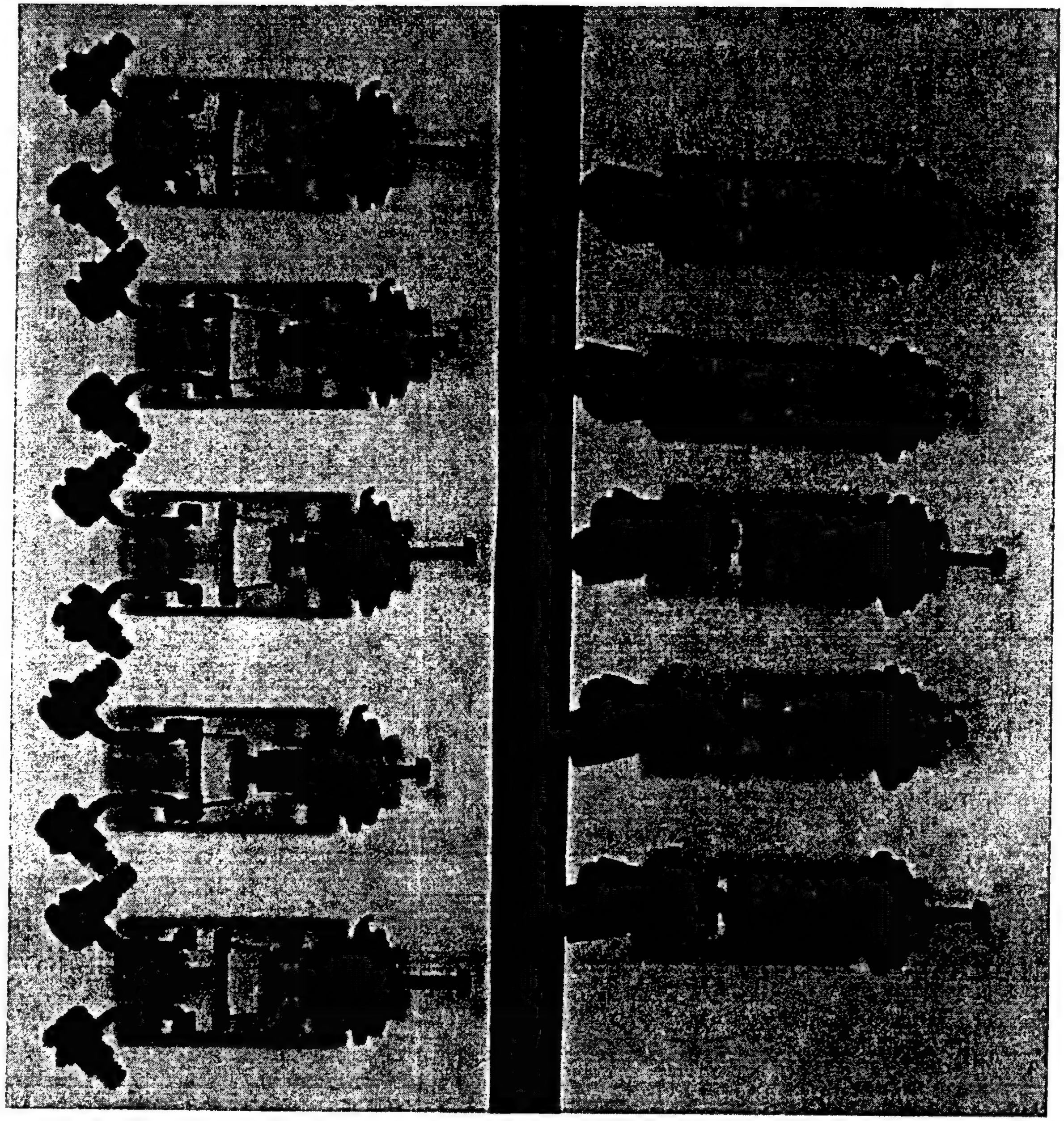
BE039

BE040

BH045

BH046

BH047



-NX1P1

BE039

BE040

BH045

BH046

BH047

Process 1: (Box 1)

Lines 41-45

-WX1P1

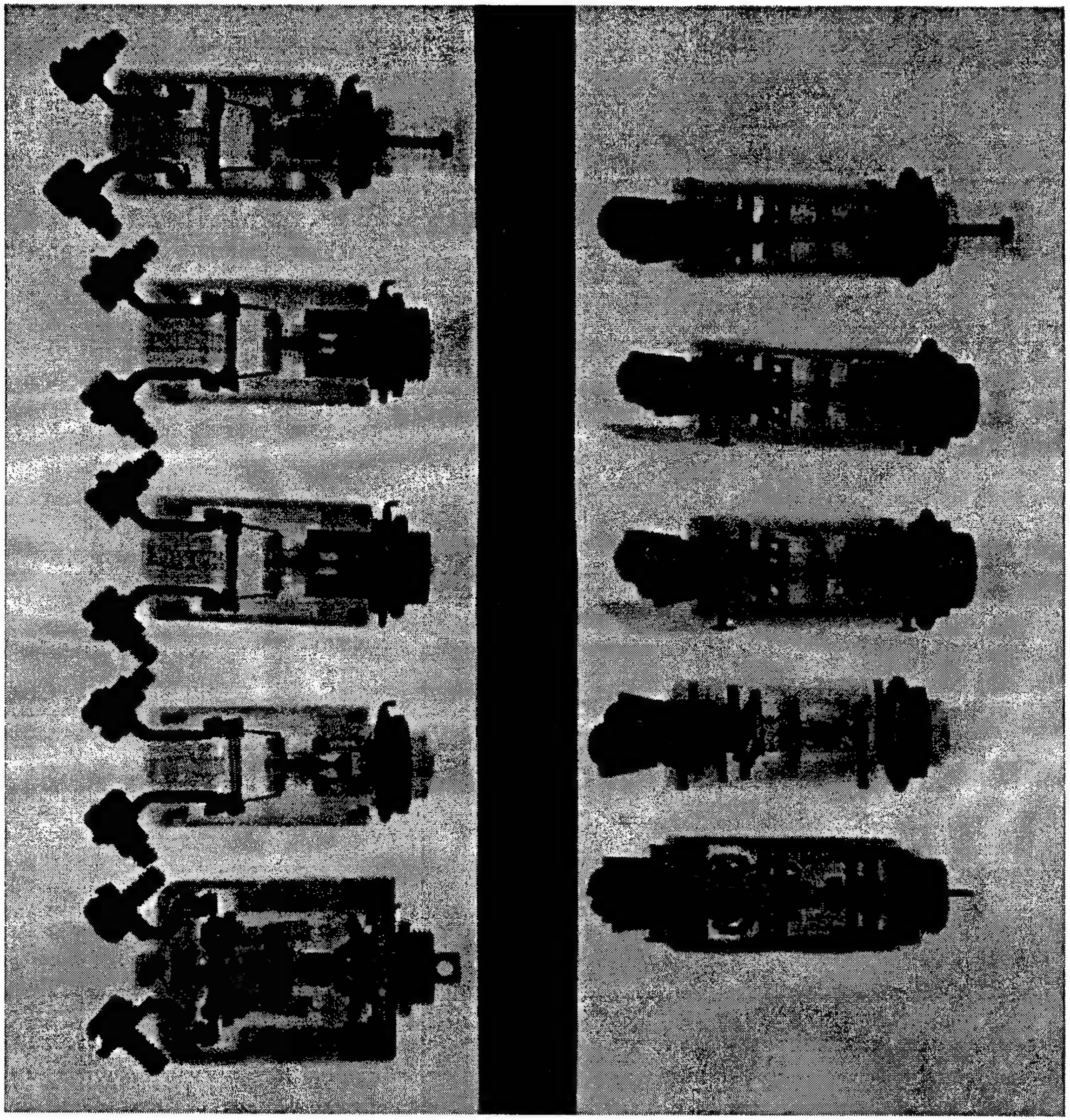
CD066

CD067

CD0668

CE079

CH084



-NX1P1

CD066

CD067

CD068

CE079

CH084

Process 1: (Box 1)

Lines 46-50

-WX1P1

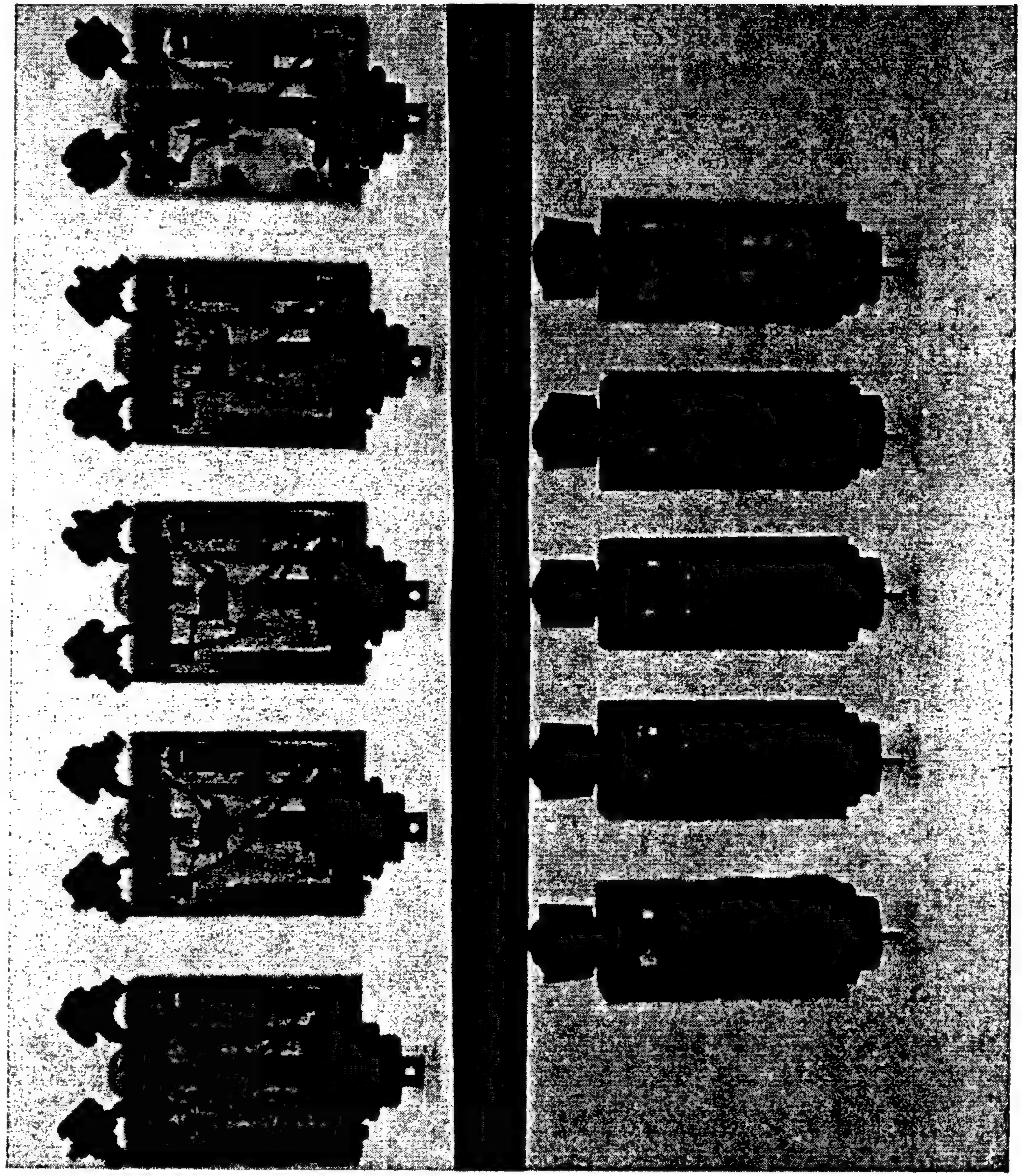
DA091

DA092

DA093

DA094

DA095



-NX1P1

DA091

DA092

DA093

DA094

DA095

Process 1: (Box 1)

Lines 51-55

-WX1P1

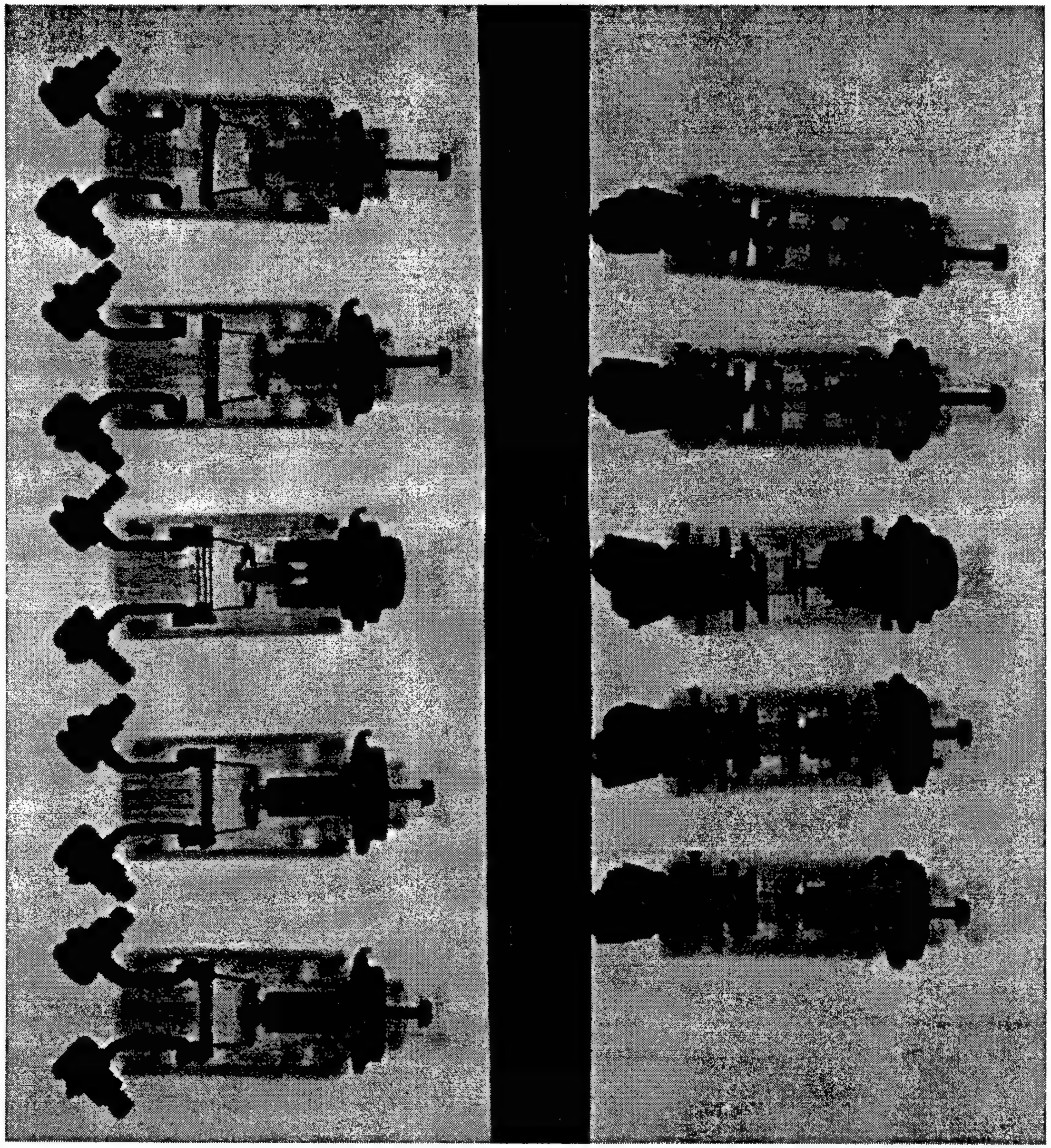
DE116

DE117

DE118

DH137

DH138



-NX1P1

DE116

DE117

DE118

DH137

DH138

Process 1: (Box 1)

Lines 56-60

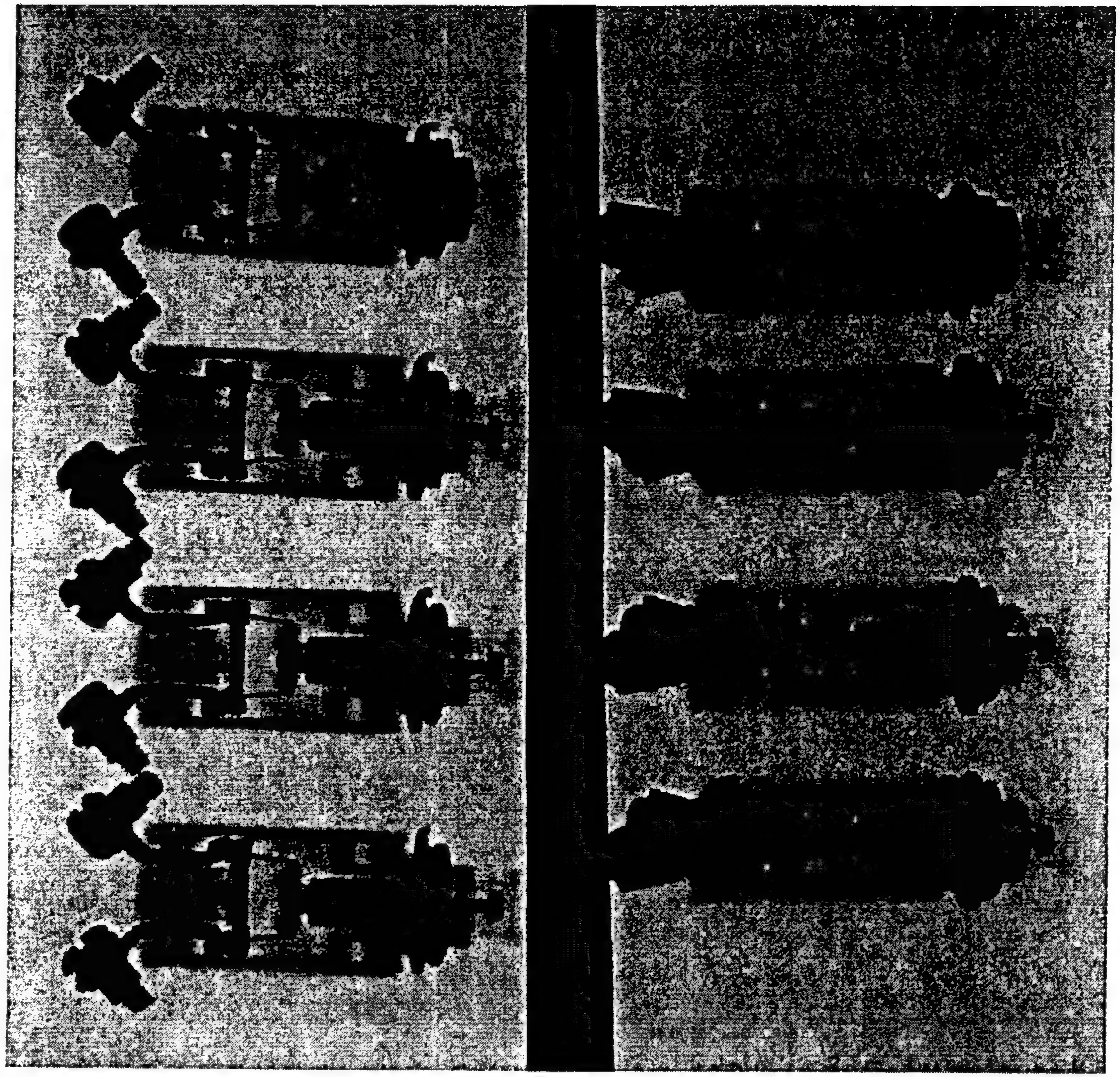
-WX1P4

AE007

BD027

BE039

BH045



-NX1P4

AE007

BD027

BE039

BH045

Process 1: (Box 4)

Lines 33, 38, 41, 43

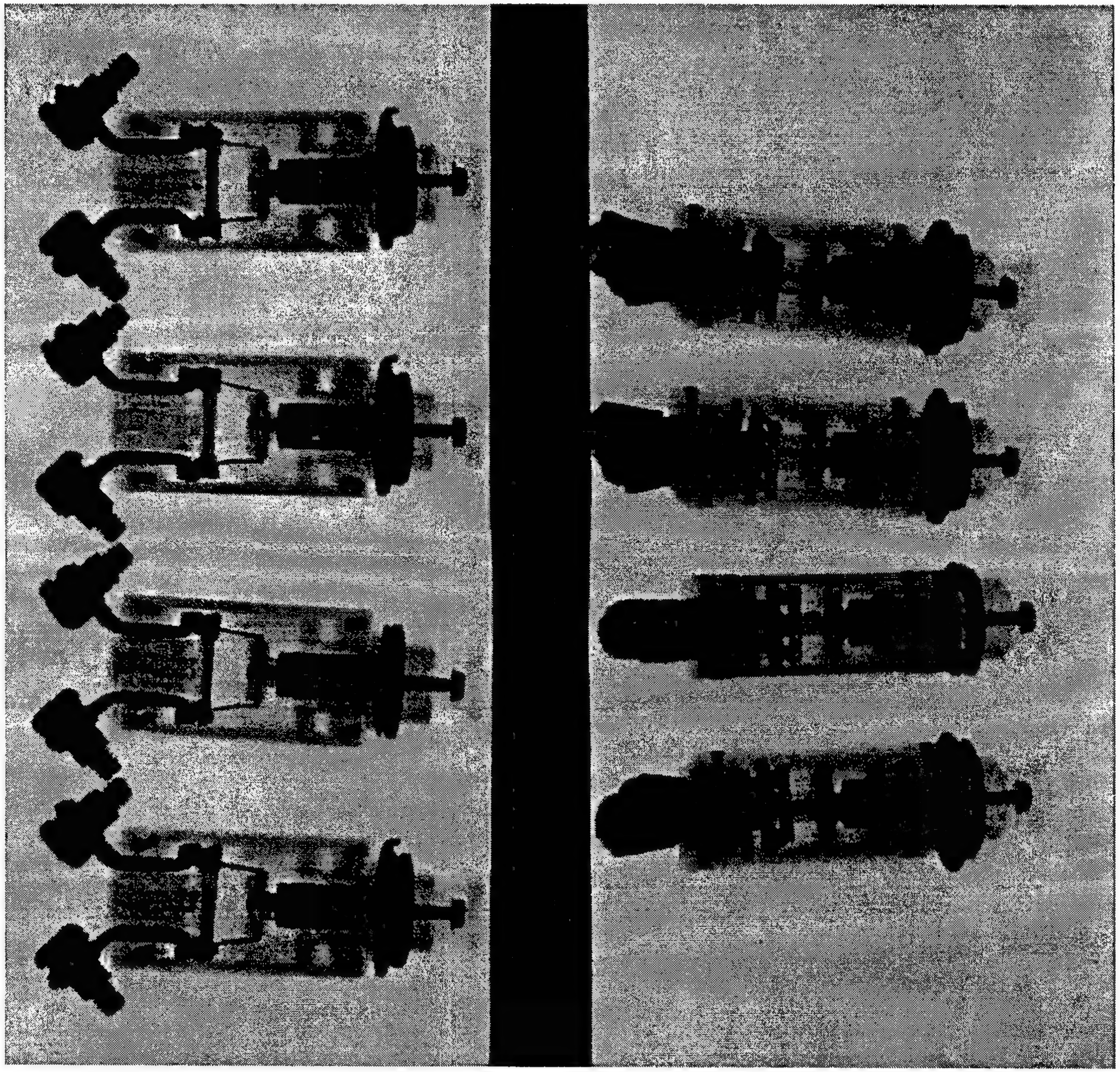
-WX1P4

BH047

CD066

DE116

DE117



-NX1P4

BH047

CD066

DE116

DE117

Process 1: (Box 4)

Lines 45, 46, 56, 57

-WX1P1

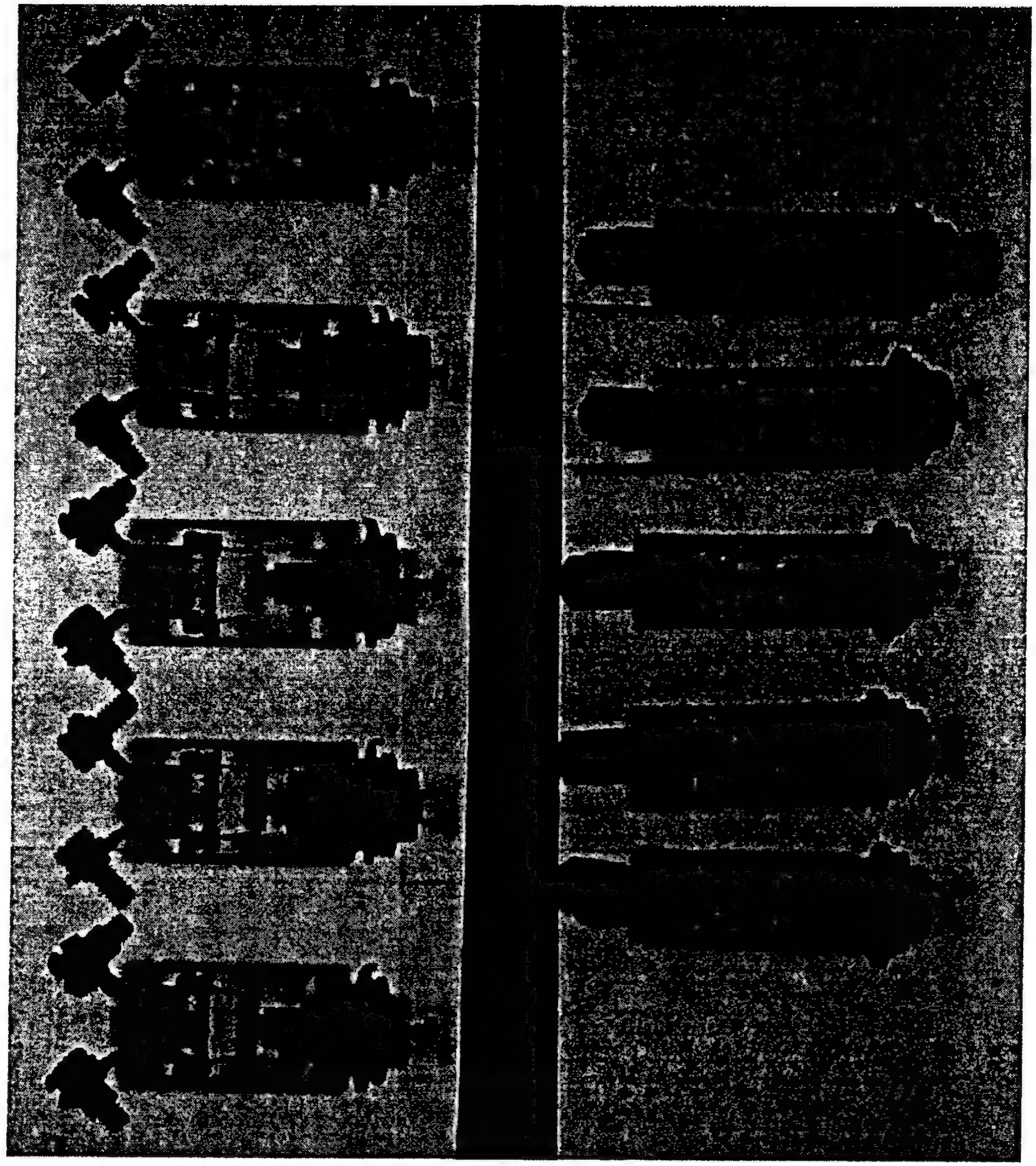
GB301

IB302

BD303

CD304

AE305



-NX1P1

GB301

IB302

BD303

CD304

AE305

Process 1: (Box 1)

Lines 278-282

-WX1P1

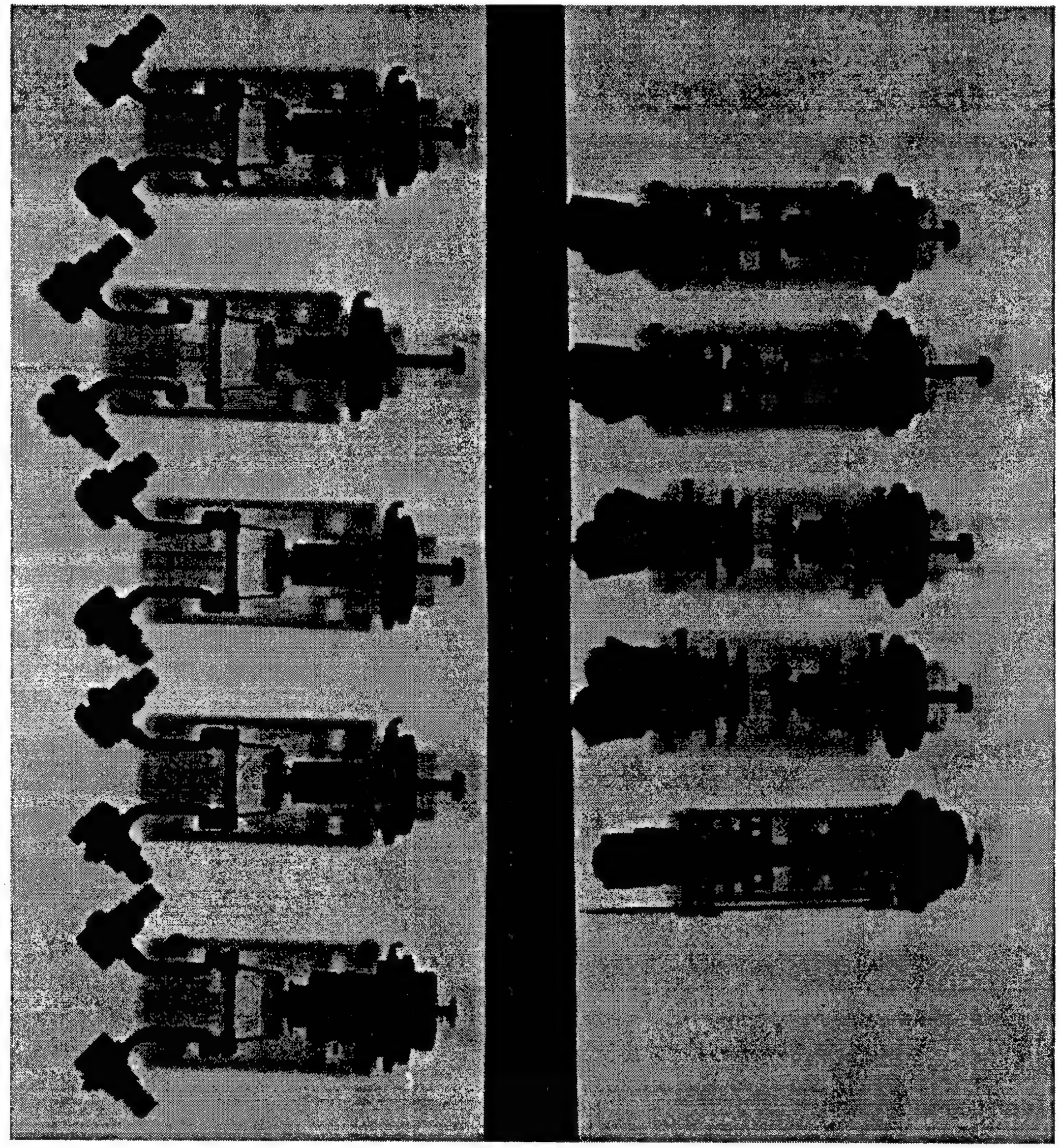
BE306

DE307

BH308

DH309

ED310



-NX1P1

BE306

DE307

BH308

DH309

ED310

Process 1: (Box 1)
Lines 283-287

-WX1P1

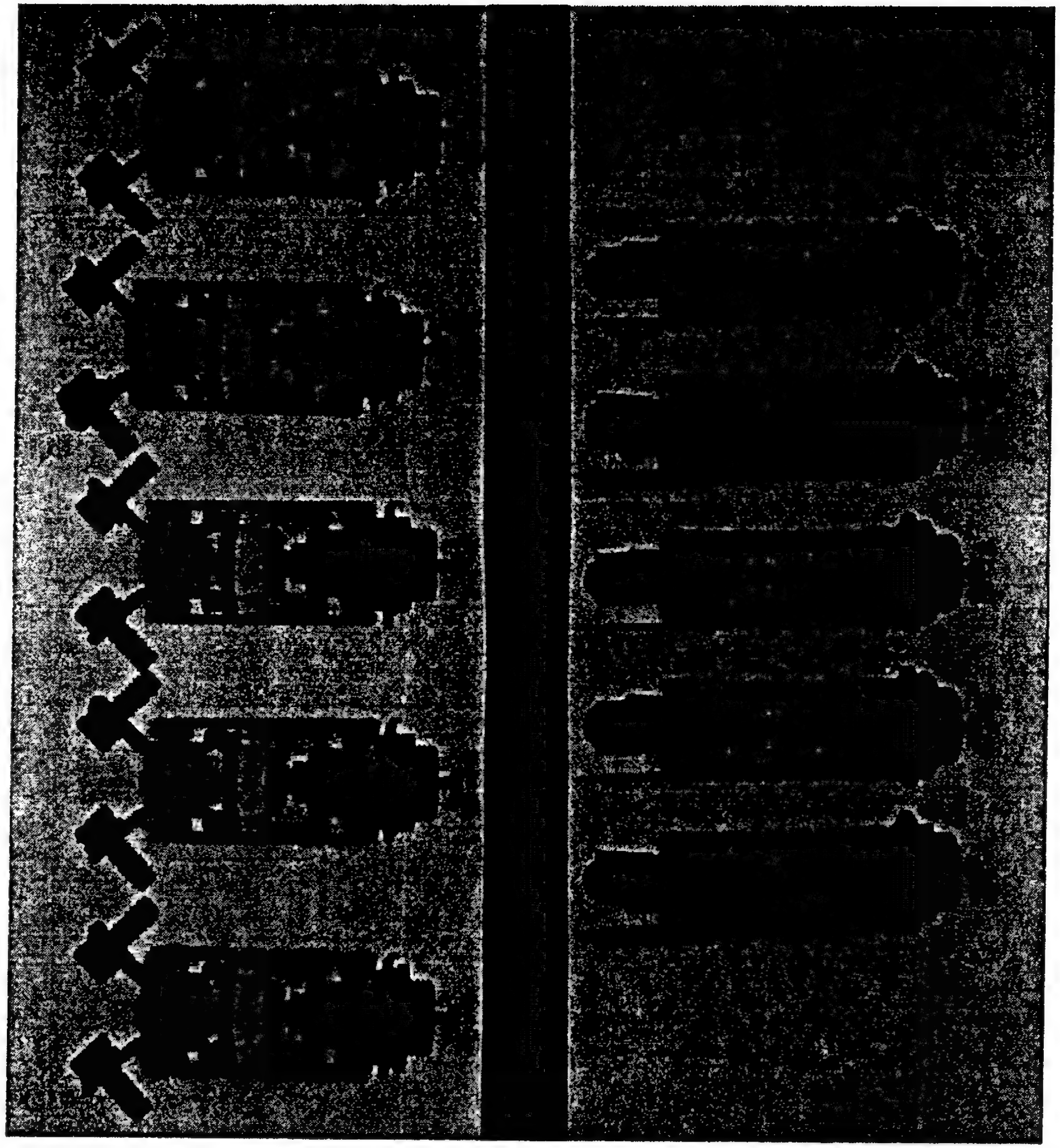
JD311

EE312

LE313

JH314

KH315



-NX1P1

JD311

EE312

LE313

JH314

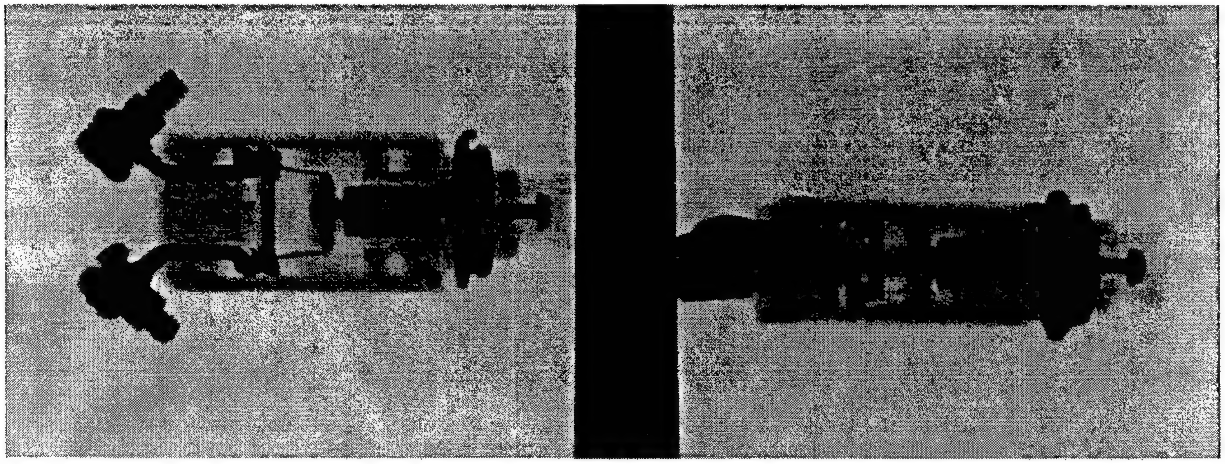
KH315

Process 1: (Box 1)

Lines 288-292

-WX1P4

DE307



-NX1P4

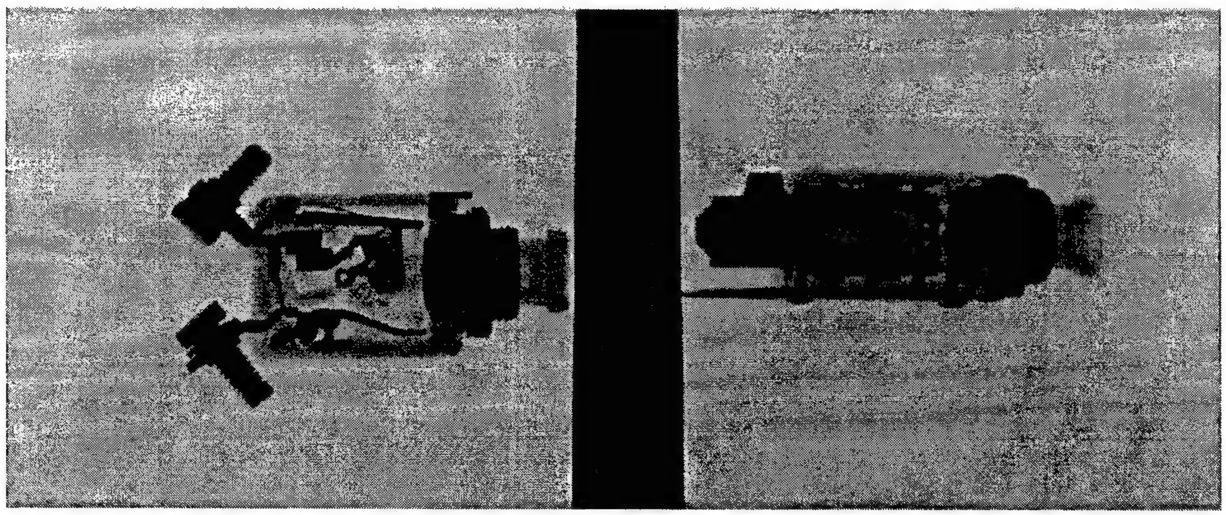
DE307

Process 1: (Box 4)

Lines 284

-WX2P1

ED153

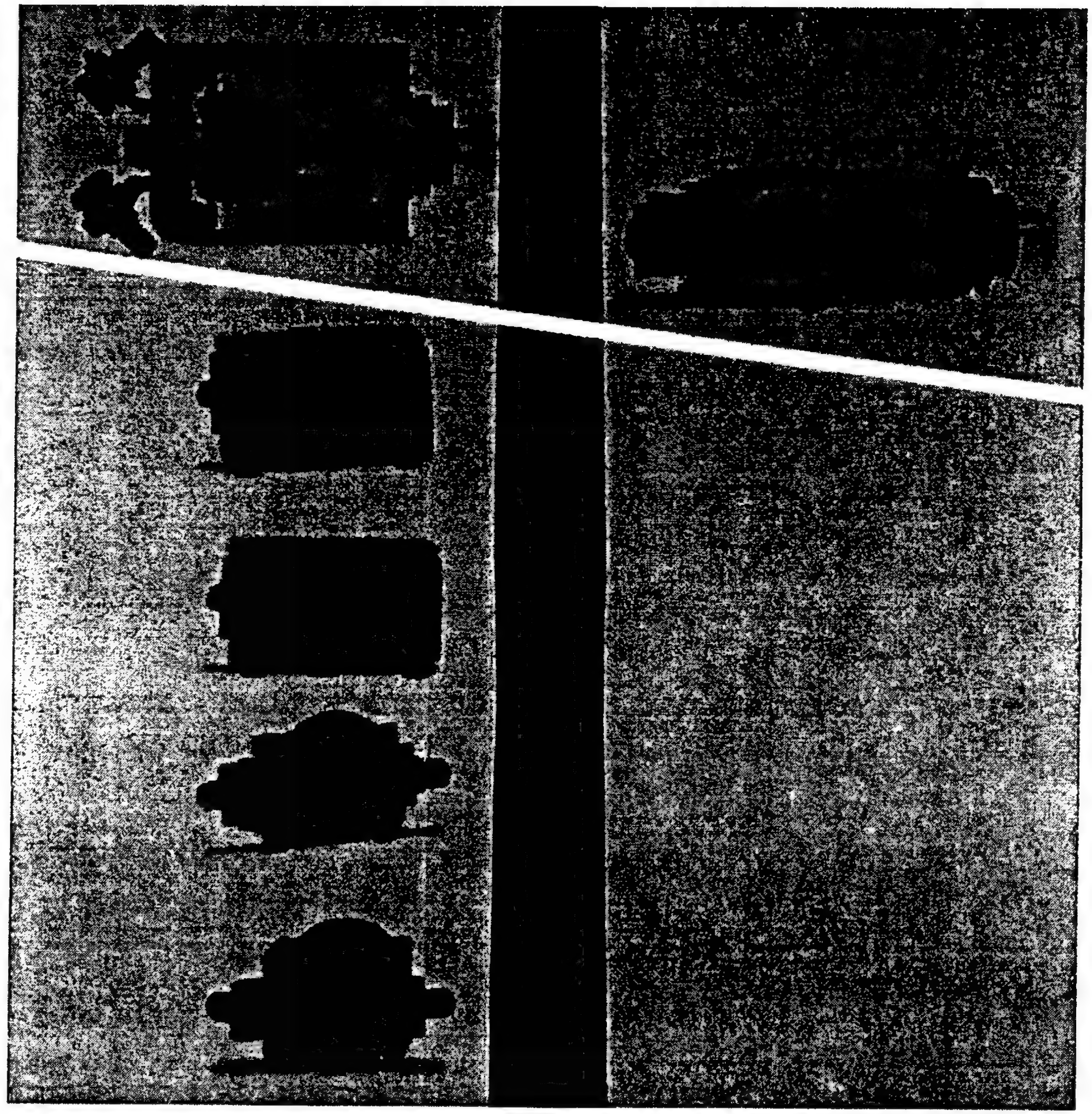


-NX2P1

ED153

Process 2: (Box 1)

Lines 293


-WX2P1
LJ316
-BX1P8
EE191
GE200
HD213
EE312
-NX1P1
LJ316
Process 2: (Box 1)
Line 294
Process 1: (Box 8)
Lines 295-298

APPENDIX F—PROCESS 1 RESULTS AND FAILURE ANALYSIS REPORTS

F.1 PROCESS 1 RESULTS.

Block Number (#)	Manufacturer		Visual (See Inventory Sheet) & X-Ray Photo # (1)		(2)	Open Breakers only: Close & X-Ray Photo # (3) (4)		(5)	150% or 200% Overload Cal. (6)					(10)	(11)	400%, 500% or 600% Overload Cal. (12)					(16)	Comments Provided below	X-Ray Button View
Sample Number	Part Designator	Date Code	Sample#-Wide View	Sample#-Narrow View	Breaker Open/ Closed	Sample#-Wide View	Sample#-Narrow View	L.V.C.R. Avg (mV)	LVCR Max (mV)	Temp. Rise (°C)	Overload %	P/F ? (7)	Close Breaker	L.V.C.R. Avg (mV)	LVCR Max (mV)	Temp. Rise (°C)	Overload %	P/F ? (13)	L.V.C.R. Avg (mV)	(1,2, etc)	Sample#-Button
AD001	A - 3	0974A	WX1P1	NX1P1	Closed			17.1	253	4	200	Pass	X	55.04	105	1	500	Pass	25.56	4	
AD002	A - 3	0974A	WX1P1	NX1P1	Closed			14.56	258	5	200	Pass	X	35.68	71	1	500	Pass	45.71	4	
AE007	A - 5	1091A	WX1P1	NX1P1	Open	WX1P4	NX1P4	8.14												2	
AE008	A - 5	0792A	WX1P1	NX1P1	Closed			7.92	234	4	200	Pass	X	11.50	32	3	500	Pass	8.04	4	
AH012	A - 10	0974A	WX1P1	NX1P1	Closed			2.27	244	6	200	Pass	X	3.25	126	4	500	Pass	5.75	4	
BA020	L - .5	7207	WX1P1	NX1P1	Closed			489.35	430	2	200	Pass	X	488.20			N/A			3	
BA021	L - .5	8203	WX1P1	NX1P1	Closed			449.18	396	3	200	Pass	X	450.70			N/A			3	
BD027	A - 3	0374A	WX1P1	NX1P1	Open	WX1P4	NX1P4	16.39												2	
BD028	A - 3	0874A	WX1P1	NX1P1	Closed			17.44	333	8	200	Pass	X	88.08	88	2	500	Pass	232.58	4	
BD029	A - 3	0374A	WX1P1	NX1P1	Closed			15.74	328	5	200	Pass	X	58.62	201	3	500	Pass	21.25	4	
BE039	A - 5	0674A	WX1P1	NX1P1	Open	WX1P4	NX1P4	7.84												2	
BE040	A - 5	0674A	WX1P1	NX1P1	Closed			7.94	198	6	200	Pass	X	48.89	125	3	500	Pass	25.54	4	
BH045	A - 10	0674A	WX1P1	NX1P1	Open	WX1P4	NX1P4	2.24	345	6	200	Pass	X	10.76	94	4	500	Pass	5.23	4	
BH046	A - 10	0674A	WX1P1	NX1P1	Closed			2.45												2	
BH047	A - 10	0674A	WX1P1	NX1P1	Closed			2.32	220	5	200	Pass	X	2.00	62	5	500	Pass	5.00	4	
CD066	A - 3	0874A	WX1P1	NX1P1	Open	WX1P4	NX1P4	17.18												2	
CD067	B - 3	0489A	WX1P1	NX1P1	Closed			16.05	295	4	200	Pass	X	59.41	75	3	500	Pass	16.19	4	
CD068	B - 3	0887A	WX1P1	NX1P1	Closed			16.4	266	6	200	Pass	X	28.79	158	3	500	Pass	35.80	4	
CE079	A - 5	0289A	WX1P1	NX1P1	Closed			7.47	254	7	200	Pass	X	12.34	13	4	500	Pass	10.57	4	
CH084	H - 10	7807	WX1P1	NX1P1	Closed			2.52	219	0	200	Pass	X	3.17			N/A			3	
DA091	L - .5	9346	WX1P1	NX1P1	Closed			454.13	441	0	200	Pass	X	455.10			N/A			3	
DA092	L - .5	7417	WX1P1	NX1P1	Closed			458.77	424	0	200	Pass	X	459.50			N/A			3	
DA093	L - .5	7425	WX1P1	NX1P1	Closed			465.55	339	4	200	Pass	X	453.70			N/A			3	
DA094	L - .5	7408	WX1P1	NX1P1	Closed			455.27	391	4	200	Pass	X	455.80			N/A			3	
DA095	L - .5	7439	WX1P1	NX1P1	Closed			474.6	496	4	200	Pass	X	474.30			N/A			3	
DE116	A - 5	0874A	WX1P1	NX1P1	Open	WX1P4	NX1P4	7.88												2	
DE117	A - 5	0874A	WX1P1	NX1P1	Open	WX1P4	NX1P4	8.18	234	7	200	Pass	X	61.95	104	2	500	Pass	10.40	4	
DE118	A - 5	0996	WX1P1	NX1P1	Closed			8.18	233	8	200	Pass	X	25.72	4	4	500	Pass	20.96	4	
DH137	A - 10	1274A	WX1P1	NX1P1	Closed			2.16	245	3	200	Pass	X	2.72	157	2	500	Pass	2.97	4	
DH138	A - 10	0974A	WX1P1	NX1P1	Closed			2.61												2	
BD303	A - 3	0374A	WX1P1	NX1P1	Closed			118.7	286	7	200	Pass	X	67.63	57	1	500	Pass	56.30	4	
CD304	B - 3	9138	WX1P1	NX1P1	Closed			17.85	276	7	200	Pass	X	19.13	74	2	500	Pass	17.92	4	
AE305	A - 5	0874A	WX1P1	NX1P1	Closed			12.07	375	1	200	Pass	X	7.82	192	4	500	Pass	10.93	4	
BE306	A - 5	0674A	WX1P1	NX1P1	Closed			12.05	305	6	200	Pass	X	20.29	65	3	500	Pass	20.50	4	
DE307	A - 5	0874A	WX1P1	NX1P1	Open	WX1P4	NX1P4	112.06	296	5	200	Pass	X	10.81	41	5	500	Pass	14.07	4	
BH308	A - 10	0674A	WX1P1	NX1P1	Closed			9.86	267	1	200	Pass	X	5.42	34	3	500	Pass	3.38	4	
DH309	A - 10	0974A	WX1P1	NX1P1	Closed			1.98	202	2	200	Pass	X	6.94	31	3	500	Pass	2.25	4	
EH184	B - 1	0575A	WX1P1	NX1P1	Closed			6.72	212	3	200	Pass	X	3.13	51	2	500	Pass	2.01	4	
FH188	B - 5	1173A	WX1P1	NX1P1	Closed			13.07												2	
FH189	B - 10	0873A	WX1P1	NX1P1	Closed			7.08	250	5	200	Pass	X	2.35	49	3	500	Pass	2.24	4	
FE190	B - 5	1173A	WX1P1	NX1P1	Closed			13.41	397	0	200	Pass	X	24.92	53	4	500	Pass	97.72	4	
EE191	G - 5	7350	WX1P1	NX1P1	Closed			12.36	257	3	200	Fail								4	BX1P8
EB192	B - 1	1268A	WX1P1	NX1P1	Closed			182.34	375	1	200	Pass	X	176.48	56	3	500	Pass	169.72	4	
GD198	B - 3	0369A	WX1P1	NX1P1	Open	WX1P4	NX1P4	21.66	243	3	200	Pass	X	27.59	1644	2	500	Pass	17.40	4	
GB199	B - 1	1087A	WX1P1	NX1P1	Closed			180.36												2	
GE200	G - 5	7349	WX1P1	NX1P1	Closed			12.28	214	3	200	Fail								4	BX1P8
HD213	B - 3	0569A	WX1P1	NX1P1	Open	WX1P4	NX1P4	Failed									500			1	BX1P8
HE217	B - 5	1173A	WX1P1	NX1P1	Closed			13.45	219	1	200	Pass	X	21.73	66	3	500	Pass	8.53	4	

			Failure Analysis (8) and (14)						Retest Failed Cal.Test (perform test that failed originally)								
Block Number (#)	Manufacturer		If Failure: Prior to Cycling breaker	Cycle breaker once and retest	breaker 2nd time and retest.	breaker 3rd time and retest.	breaker 4th time and retest.	breaker 5th time and retest.	200% Overload (s)			500% Overload (s)			Send CB to manufacturer		
Sample Number	Part Designator	Date Code	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR Max (mV)	Temp. Rise (°C)	P/F ?	LVCR Max (mV)	Temp Rise (°C)	P/F ?	Date Sent	Manf. FA #	Date Returned
AD001	A - 3	0974A															
AD002	A - 3	0974A															
AE007	A - 5	1091A															
AE008	A - 5	0792A															
AH012	A - 10	0974A															
BA020	L - .5	7207															
BA021	L - .5	8203															
BD027	A - 3	0374A															
BD028	A - 3	0874A															
BD029	A - 3	0374A															
BE039	A - 5	0674A															
BE040	A - 5	0674A															
BH045	A - 10	0674A															
BH046	A - 10	0674A															
BH047	A - 10	0674A															
CD066	A - 3	0874A															
CD067	B - 3	0489A															
CD068	B - 3	0887A															
CE079	A - 5	0289A															
CH084	H - 10	7807															
DA091	L - .5	9346															
DA092	L - .5	7417															
DA093	L - .5	7425															
DA094	L - .5	7408															
DA095	L - .5	7439															
DE116	A - 5	0874A															
DE117	A - 5	0874A															
DE118	A - 5	0996															
DH137	A - 10	1274A															
DH138	A - 10	0974A															
BD303	A - 3	0374A															
CD304	B - 3	9138															
AE305	A - 5	0874A															
BE306	A - 5	0674A															
DE307	A - 5	0874A															
BH308	A - 10	0674A															
DH309	A - 10	0974A															
EH184	B - 1	0575A															
FH188	B - 5	1173A															
FH189	B - 10	0873A															
FE190	B - 5	1173A															
EE191	G - 5	7350	8.04	7.97	7.93	7.92	8.57	8.94	168	1	Fail				9/6/01		
EB192	B - 1	1268A															
GD198	B - 3	0369A															
GB199	B - 1	1087A															
GE200	G - 5	7349	13.18	9.17	8.72	8.51	12.07	15.45	135	2	Fail				9/6/01		
HD213	B - 3	0569A	0.00	0.00	0.00	0.00	0.00	0.00							9/6/01		
HE217	B - 5	1173A															

Block Number (#)	Manufacturer		Visual (See Inventory Sheet) & X-Ray Photo # (1)		(2)	Open Breakers only: Close & X-Ray Photo # (3) (4)		(5)	150% or 200% Overload Cal. (6)				(10)	(11)	400%, 500% or 600% Overload Cal. (12)				(16)	Comments Provided below	X-Ray Button View
Sample Number	Part Designator	Date Code	Sample#-Wide View	Sample#-Narrow View	Breaker Open/ Closed	Sample#-Wide View	Sample#-Narrow View	L.V.C.R. Avg (mV)	LVCR Max (mV)	Temp. Rise (°C)	Overload %	P/F ? (7)	Close Breaker	L.V.C.R. Avg (mV)	LVCR Max (mV)	Temp. Rise (°C)	Overload %	P/F ? (13)	L.V.C.R. Avg (mV)	(1,2, etc)	Sample#-Button
HH221	B - 10	0873A	WX1P1	NX1P1	Open	WX1P4	NX1P4	7.12	205	7	200	Pass	X	2.48	85	1	500	Pass	2.30	4	
IB230	B - 1	1168A	WX1P1	NX1P1	Closed			179.97												2	
IB231	K - 1	9043	WX1P1	NX1P1	Closed			149.2	419	4	200	Pass	X	172.48	577	2	500	Pass	236.56	4	
IB232	B - 1	9128	WX1P1	NX1P1	Closed			178.65	458	3	200	Pass	X	170.27	81	4	500	Pass	178.74	4	
ID237	B - 3	0569A	WX1P1	NX1P1	Closed			22.03												2	
JD244	J - 3	7333	WX1P1	NX1P1	Closed			53.72												2	
JD245	B - 3	0673A	WX1P1	NX1P1	Closed			22.06	274	4	200	Pass	X	49.99	282	1	500	Pass	33.71	4	
JE253	B - 5	1268A	WX1P1	NX1P1	Closed			14.05	260	2	200	Pass	X	13.80	135	4	500	Pass	15.66	4	
JH255	G - 10	8045	WX1P1	NX1P1	Closed			7.79												2	
KD258	B - 3	1083A	WX1P1	NX1P1	Closed			10.85	245	4	200	Pass	X	16.36	43	1	500	Pass	18.97	4	
KD259	B - 3	0369A	WX1P1	NX1P1	Closed			10.68	249	4	200	Pass	X	17.36	98	3	500	Pass	17.08	4	
KE262	G - 5	7350	WX1P1	NX1P1	Closed			5.93												2	
KH265	B - 10	0373A	WX1P1	NX1P1	Closed			9.12	221	7	200	Pass	X	121.07	76	3	500	Pass	51.44	4	
KH266	B - 10	0973A	WX1P1	NX1P1	Closed			7.46												2	
LB270	B - 1	0569A	WX1P1	NX1P1	Closed			178.31	421	4	200	Pass	X	208.45	12	5	500	Pass	221.40	4	
LD279	B - 3	0569A	WX1P1	NX1P1	Closed			8.33	363	2	200	Pass	X	20.60	48	4	500	Pass	15.86	4	
LE281	B - 5	1173A	WX1P1	NX1P1	Closed			8.65												2	
LE282	B - 5	1173A	WX1P1	NX1P1	Open	WX1P4	NX1P4	7.93	236	2	200	Pass	X	10.95	32	3	500	Pass	8.35	4	
LH287	B - 10	0873A	WX1P1	NX1P1	Closed			2.19	273	4	200	Pass	X	11.13	56	4	500	Pass	11.43	4	
GB301	B - 1	1185A	WX1P1	NX1P1	Closed			168.37	466	4	200	Pass	X	168.89	23	4	500	Pass	221.12	4	
IB302	B - 1	0569A	WX1P1	NX1P1	Closed			172.57	440	3	200	Pass	X	182.65	118	5	500	Pass	168.13	4	
ED310	B - 3	0569A	WX1P1	NX1P1	Closed			24.96	282	2	200	Pass	X	20.14	51	4	500	Pass	84.15	4	
JD311	B - 3	0973A	WX1P1	NX1P1	Closed			21.75	262	2	200	Pass	X	111.82	44	4	500	Pass	17.36	4	
EE312	B - 5	1173A	WX1P1	NX1P1	Closed			264.23	0	0	200	Fail								5	BX1P8
LE313	B - 6	1173A	WX1P1	NX1P1	Closed			36.59	204	3	200	Pass	X	13.94	39	3	500	Pass	11.61	4	
JH314	B - 10	1273A	WX1P1	NX1P1	Closed			30.9	241	5	200	Pass	X	3.06	49	4	500	Pass	96.56	4	
KH315	B - 10	0973A	WX1P1	NX1P1	Closed			3.61	232	5	200	Pass	X	44.19	34	3	500	Pass	3.02	4	

Notes:
1. Circuit breaker would not stay mechanically closed.
2. Circuit breakers removed from test due to initial current surges during LVCR test.
3. Circuit breaker has no higher percent overload requirement
4. Circuit breaker exposed to current surges during initial LVCR test.
5. LVCR value, during 200% repeat test, exceeded reading capability of the test equipment

Block Number (#)	Manufacturer		If Failure Prior to Cycling breaker	Cycle breaker once and retest	breaker 2nd time and retest.	breaker 3rd time and retest.	breaker 4th time and retest.	breaker 5th time and retest.	200% Overload (s)			500% Overload (s)			Send CB to manufacturer		
Sample Number	Part Designator	Date Code	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR (mV)	LVCR Max (mV)	Temp. Rise (°C)	P/F ?	LVCR Max (mV)	Temp Rise (°C)	P/F ?	Date Sent	Manf. FA #	Date Returned
HH221	B - 10	0873A															
IB230	B - 1	1168A															
IB231	K - 1	9043															
IB232	B - 1	9128															
ID237	B - 3	0569A															
JD244	J - 3	7333															
JD245	B - 3	0673A															
JE253	B - 5	1268A															
JH255	G - 10	8045															
KD258	B - 3	1083A															
KD259	B - 3	0369A															
KE262	G - 5	7350															
KH265	B - 10	0373A															
KH266	B - 10	0973A															
LB270	B - 1	0569A															
LD279	B - 3	0569A															
LE281	B - 5	1173A															
LE282	B - 5	1173A															
LH287	B - 10	0873A															
GB301	B - 1	1185A															
IB302	B - 1	0569A															
ED310	B - 3	0569A															
JD311	B - 3	0973A															
EE312	B - 5	1173A	327.78	195.52	302.72	312.14	315.82	317.48	0.00	2	Fail				9/6/01		
LE313	B - 5	1173A															
JH314	B - 10	1273A															
KH315	B - 10	0973A															

Notes:
1. Circuit breaker would not stay n
2. Circuit breakers removed from t
3. Circuit breaker has no higher pe
4. Circuit breaker exposed to curre
5. LVCR value, during 200% repea

F.2 FAILURE ANALYSIS REPORTS.

DATE 9/7/01	MECHANICAL PRODUCTS FAILURE ANALYSIS REPORT	REPORT # 847
PART NUMBER 700-013-5	CUSTOMER FAA - RAYTHEON TECHNICAL SERVICES	S/N GE200
PART NAME CIRCUIT BREAKER	CUSTOMER PART NUMBER BACC18R5B	FILE CODE ja0907-1.far
TESTING BY DEPARTMENT 97 & 98	ANALYSIS AND/OR TEARDOWN BY DEPT. 97	CORRECTIVE ACTION BY DEPT.

STATEMENT OF DISCREPANCY

One MP P/N 700-013-5 (5 amp), BACC18R5B circuit breaker, stamped with a date code of the 49th week of 1973, was returned to Mechanical Products for analysis on 9/6/01 by Ron Peterson, Raytheon Technical Services, as part of the ongoing Federal Aviation Administration's "Evaluation of Age Related Degradation of Circuit Breakers" project. This breaker appeared to have been marked on one side with a felt pen as "GE200".

The documentation received at MP pertaining to unit "GE200" (Attachment 1) indicated Raytheon had subjected unit "GE200" to "Test Process Number 1" of the FAA's "Research Plan for the Evaluation of Age Related Degradation of Single and Three Phase Circuit Breakers" (Attachment 2). This documentation listed "GE200" as having been subjected to the "Low Voltage Contact Resistance Test" with an average voltage drop (over five runs) of 10.33 mV at 200 mA. It also listed "GE200" as having been subjected to the "Repeat 200% Overload Calibration Test" with a "Maximum Voltage Drop" of 135 mV, a "Maximum Temperature Rise" of 2°C, and an "Actual Trip Time" of 13.9 seconds. The "Results" column listed the unit as "fail", presumably based on the 13.9 sec. trip time being below the 15 second minimum specification limit (previously provided to Raytheon by Mechanical Products, based on Boeing Part Standard BACC18R5B).

ANALYSIS

Visual Examination

The breaker was externally examined. There was both terminal and mounting hardware attached to the breaker, presumably the hardware that was used in the aircraft application. Mechanical Products' Final Inspection and Functional Test department stamps were visible on the breaker case. These stamps, as well as the original part number stamping, Mechanical Products name, and the felt pen ID applied prior to receipt by MP are shown in the photographs of Figure 1.

It was noted that the external surfaces of the breaker were very clean (as compared to others field units of similar age which have been examined by MP). However, the ampere rating on the button ("5") was covered with grime and barely visible. This grime layer also appeared on the top side of the button (with respect to the rating stamp) but did not appear on the trip indicator. The terminals were thinly coated with a black substance, primarily on the screw head side. There was some dust and grime on the terminal screws and a thin layer of gray grime on parts of the case (which could be easily removed). The mounting bushing was a dark metallic gray color (rather than black).

Radiographs were taken in the "open" condition as received (Figure 2). No anomalies were noted.

"Block 8" Testing

The breaker was then tested according to the requirements of "Block 8 - Failure Analysis (200% Overload Calibration)" of the FAA's "Research Plan for ... Circuit Breakers". During the first on/off cycle radiographs were taken of the breaker in the "closed" condition (Figure 3). The low voltage contact resistance measurements were as follows:

8.2 mV	(taken prior to cycling)
9.1	(after first cycle)
8.5	(after second cycle)
8.8	(after third cycle)
8.4	(after fourth cycle)
8.7	(after fifth cycle)

The 200% overload test results were as follows:

200% trip time (sec.)	Max. voltage drop (mV)	Terminal temperature rise (°C)
19.6	365	2

Dielectric Test

The dielectric tests of MIL-C-5809, paragraph 4.7.2 were performed with the following results (1500VAC for 1 minute):

		Leakage
CB open:	Line terminal to Load terminal	3 uA
	Line terminal to mounting sleeve	3 uA
	Load terminal to mounting sleeve	4 uA
CB closed:	Line/load terminals to mounting	4 uA

These values are within specification and well below the maximum specification of 1 mA. There was no evidence of breakdown, flashover or arcing.

Operating Force

The operating force tests of MIL-C-5809, paragraph 4.7.6 were performed 3 times with the following results:

Pullout	Reset	
4.2	5.9	pounds
4.1	5.9	
3.9	5.8	

These values are within specification (2 to 8 pounds pullout and 4 to 12 pounds reset).

Voltage Drop

The voltage drop across the breaker was measured three times at 100% of rated current per MIL-C-5809, paragraph 4.7.19 with the following results:

Voltage Drop	
183	mV
195	
207	

Although there are no maximum voltage drop limits specified for a BACC18R5B breaker, the results of this test are well within the 0.250 volt maximum specified for a 5 amp rated MS25244 breaker (MP 700-001-5).

200% Overload, Min/Max Ultimate Trip

Five 200% overload trip tests were performed per MIL-C-5809, paragraph 4.7.7.3; five 138% maximum limit of ultimate trip tests were performed per MIL-C-5809, paragraph 4.7.7.2; and five 115% minimum limit of ultimate trip tests (breaker must hold closed) were performed per MIL-C-5809, paragraph 4.7.7.1 with following results (time in seconds):

200%	138%	115%
19.7	111	NT
17.6	113	646
16.6	162	NT
19.7	176	NT
16.9	143	NT

(Note: "NT" indicates breaker did not trip during test; for the 115% hold tests temperature monitoring was not performed)

All tests results are within specification with the exception of the second 115% hold test. The specification requires the breaker to hold closed without tripping for the duration of the 115% minimum limit of ultimate trip test; the breaker tripped 646 seconds into that test.

Internal Examination

The breaker was disassembled and examined. There were a small number of tiny black flakes loose within the case cavity. The contacts showed slight surface damage and there was minor discoloration of the case near the contacts, consistent with the breaker having been cycled under load or having tripped under overloads of less than short circuit conditions. There was some wear to the electrical (bimetal) latch. There was a normal amount of lubricant present on the button latch rollers. No obvious anomalies were noted.

Due to time constraints imposed for submission of this report, additional testing and analysis were not performed.

CONCLUSIONS

The low voltage contact resistance, voltage drop, operating force, 200% overload trip, and 138% trip test results were all within specified limits. The results were all very similar to results of tests on 5 amp MP 700 Series circuit breakers built within the year 2001. All tests were performed to the requirements of MIL-C-5809 and BACC18R unless otherwise noted.

The field history of the breaker identified as "GE200" was not available at the time of this analysis.

The 200% overload trip test performed at Raytheon may have been the first time this breaker was required to open a circuit in response to an overload condition since it left Mechanical Products approximately 28 years ago. The number of manual cycles since initial installation also was not known.

The 200% overload trip time experienced at Raytheon was only 1.1 seconds under the specified 15 second minimum (less than 3% of the allowable 15 to 55 second trip range). Multiple 200% overload tests at Mechanical Products did not repeat the failure seen at Raytheon. The breaker also passed five 138% maximum ultimate trip tests and four 115% minimum ultimate trip tests at Mechanical Products. There was one failure to hold closed at 115% for the required time period.

Examination of the internal mechanism did not appear to indicate the breaker had been electrically or manually cycled much beyond the endurance limits specified in BACC18R. There were no indications that the breaker had been exposed to high current interruption or severe contamination.

The additional testing without failures indicates this breaker is probably very close to being completely within specification. The single 115% hold failure and the slightly low 200% trip time during the Raytheon testing could indicate a very slight downward shift in electrical calibration over time. A calibration shift of this type could be the result of slight wear to the electrical latch over a number of years of manual cycling. The failures could also be the result of not having exercised the electrical trip portion of the mechanism in a very long time. As noted previously, the functional history of this breaker during the approximately 28 years since it left Mechanical Products was not available.

CORRECTIVE ACTION

None requested or required.

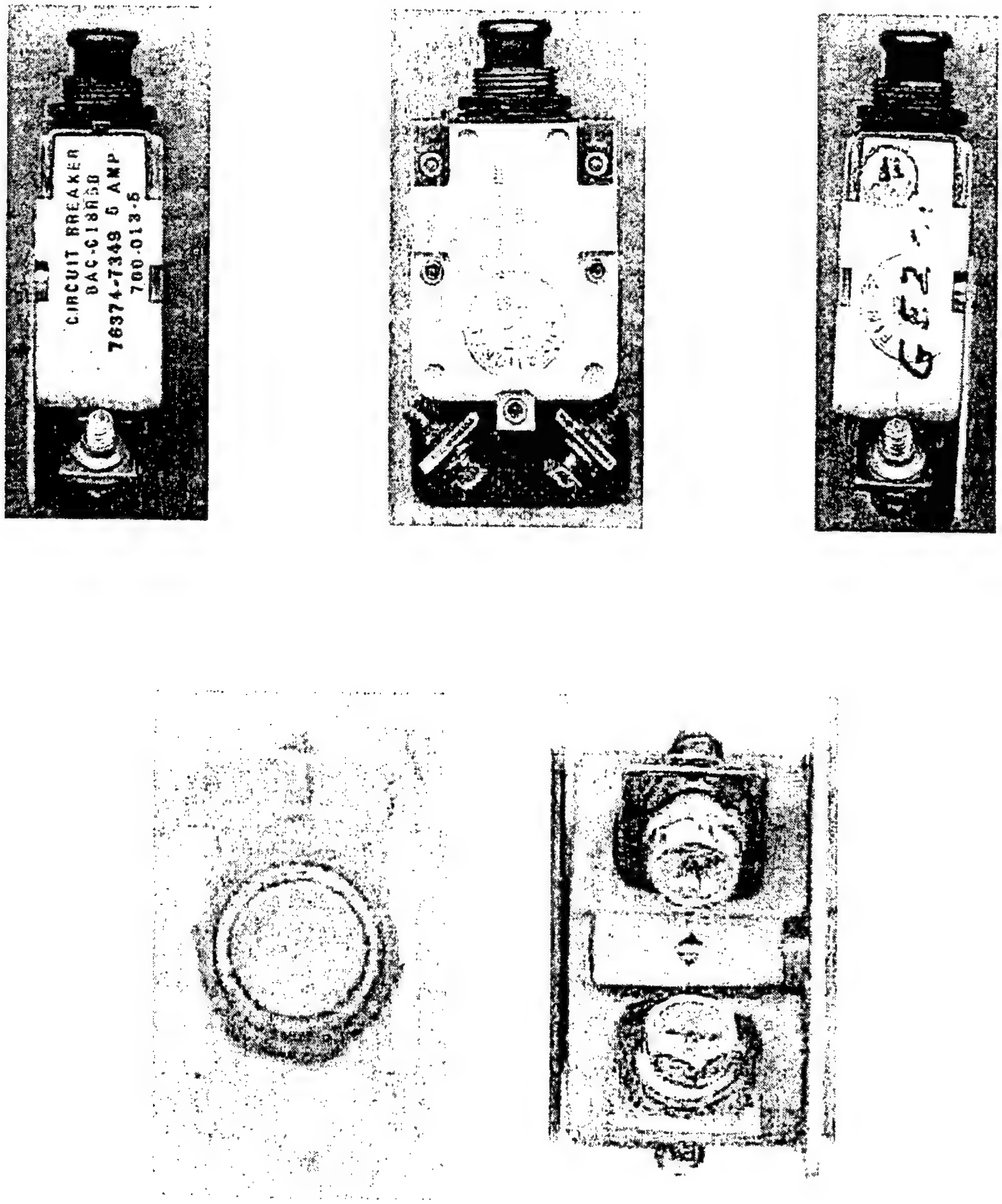


Figure 1.
Exterior of circuit breaker "GE200".

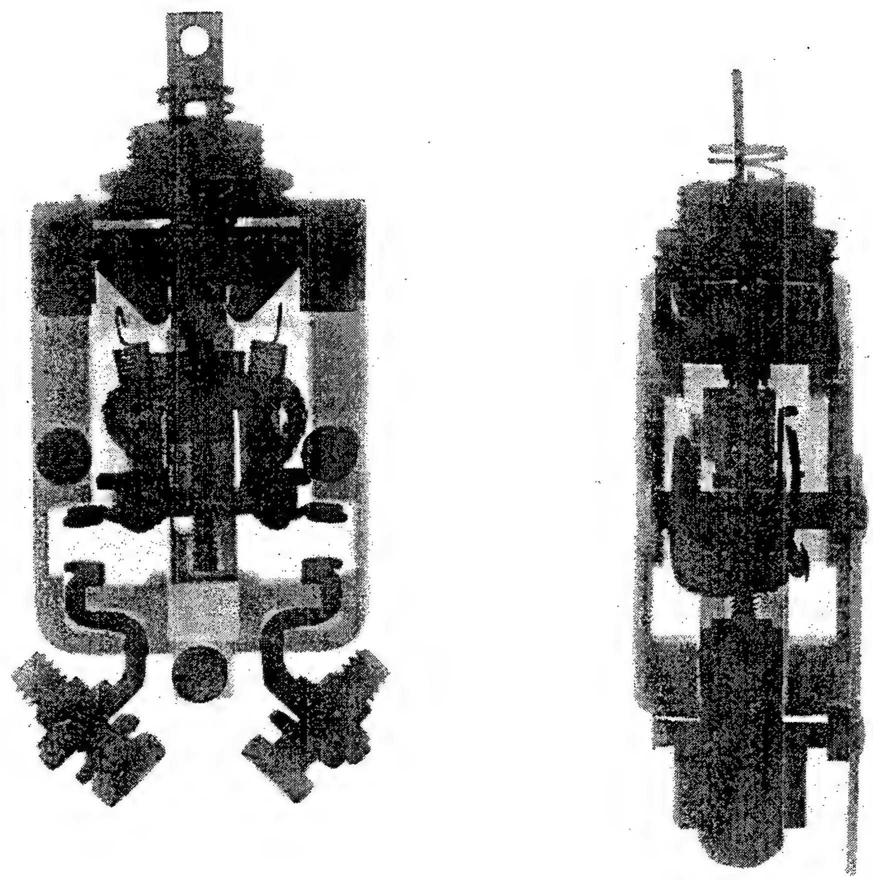


Figure 2.
Radiograph of breaker "GE200" in the open (unlatched) position as received.

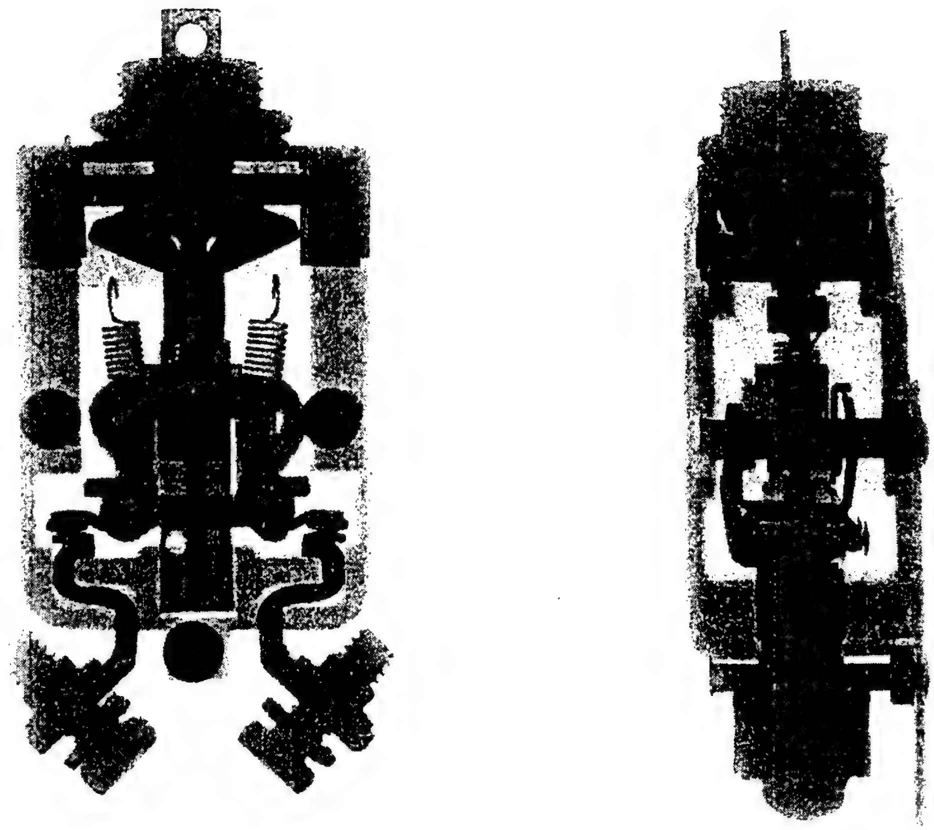


Figure 3.
Radiograph of breaker "GE200" in the closed (latched) position.

Attachment 1

Documentation received for sample "GE200"

Date: 9/5/01

To: Mechanical Products Inc.
Attn: James C. Allison
1824 River Street
Jackson, MI 49202

From: Raytheon Technical Services Company
Attn: Ronnie Peterson, M/S 37
6125 East 21ST Street
Indianapolis, IN 46219-2058

In-closed are the failed samples that occurred during our FAA testing on circuit breakers that came from aged aircraft.

You are requested to perform a failure analysis on the breakers per your agreement with the FAA representative Mr. Rob Pappas.

Please send your report by 9/12/01, so that it can be added to the FAA report to be provided by RTSC.

Please provide a separate report for each failure and designate your report by the number specified for the sample.

Regards

Ron

Ron

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
TEST LABORATORY DATA SHEET

Sample Number	Observation Notes	Report Number	x-ray wide & narrow Provid	X-ray Button View Provid	Repeat Test Compte	LVCR Info Sent	Date Sent	Date Recv	Shipping Information
HD213	1	HD213P1BS			*	*			
EE312		EE312P1B6	✓	✓	✓	✓	9/5		
EE191		EE191P1B6	✓	✓	✓	✓	9/5		
GE200		GE200P1B6			✓				

OBSERVATIONS: 1* CANNOT PERFORM LVCR, BREAKER WILL NOT STAY CLOSED. Notice Problem at block 5

Page ______

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
LABORATORY TEST DATA SHEET

Test Low Voltage Contact Resistance	Project Number 50-20-011	Date 8/30/01	Tested By GSA
Test Equipment H/P 6034A H/P 6032A Keithley 197 Keithley 197	Calibration Number 36529 40568 35205	Calibration Due 1/9/04 12/22/02 12/22/02	Specification FAA & MIL-C-5809
Process #: 1 Block #: 8	Test Temperature: 24C Soak Temperature: 24C	Test Paragraphs: Met: 4.7.17.1 & FAA Test Plan	Test Parameters Voltage (Open Circuit Volts DC): 26 ±2V

SAMPLE NUMBER	cycled 1	cycled 2	cycled 3	MEASURED VOLTAGE DROP (mV)								CURRENT
	READING #1	READING #2	READING #3	READING #4	READING #5	READING #6	READING #7	READING #8	READING #9	READING #10	READING AVERAGE	Last Reading (MILLIAMP)
EE312	327.78	195.523	302.72	312.14	315.82							200
EE191	8.043	7.967	7.927	7.915	8.570							200
GE200	13.177	9.169	8.717	8.514	12.073							200
HD213	WILL	NOT	STAY	CLOSED.		(not	tested	Notice	Problem	at block	5)	

COMMENTS: ______

Page ______

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
LABORATORY TEST DATA SHEET

	Project Number 50-20-011	Date 9/5/01	Tested By
Test Equipment Munro Q/C-20 Omega OM-400	Calibration Number 45585 39650	Calibration Due 1/8/02 8/20/02	Specification MIL-C-5809
Test Repeat 200% Overload Calibration	Test Paragraphs Req: 3.7.4 Met: 4.7.4.3		Test Process #: 1 Process Block #: 8 Ambient Temp: 26°C

SAMPLE NUMBER	CURRENT RATING (A)	MAX VOLTAGE DROP (MV)	MAX TEMP RISE (C)	REQUIRED TRIP TIME (S)	ACTUAL TRIP TIME (S)	RESULTS PASS/ FAIL
EE191	5	168	1	15-55	13.5	FAIL
FE200	5	13.5	2	15-55	13.9	FAIL
E ~~H~~3/2 ~~H312~~	3	~~0~~	2	~~20-65~~ 2-20	~~0~~	FAIL

COMMENTS:

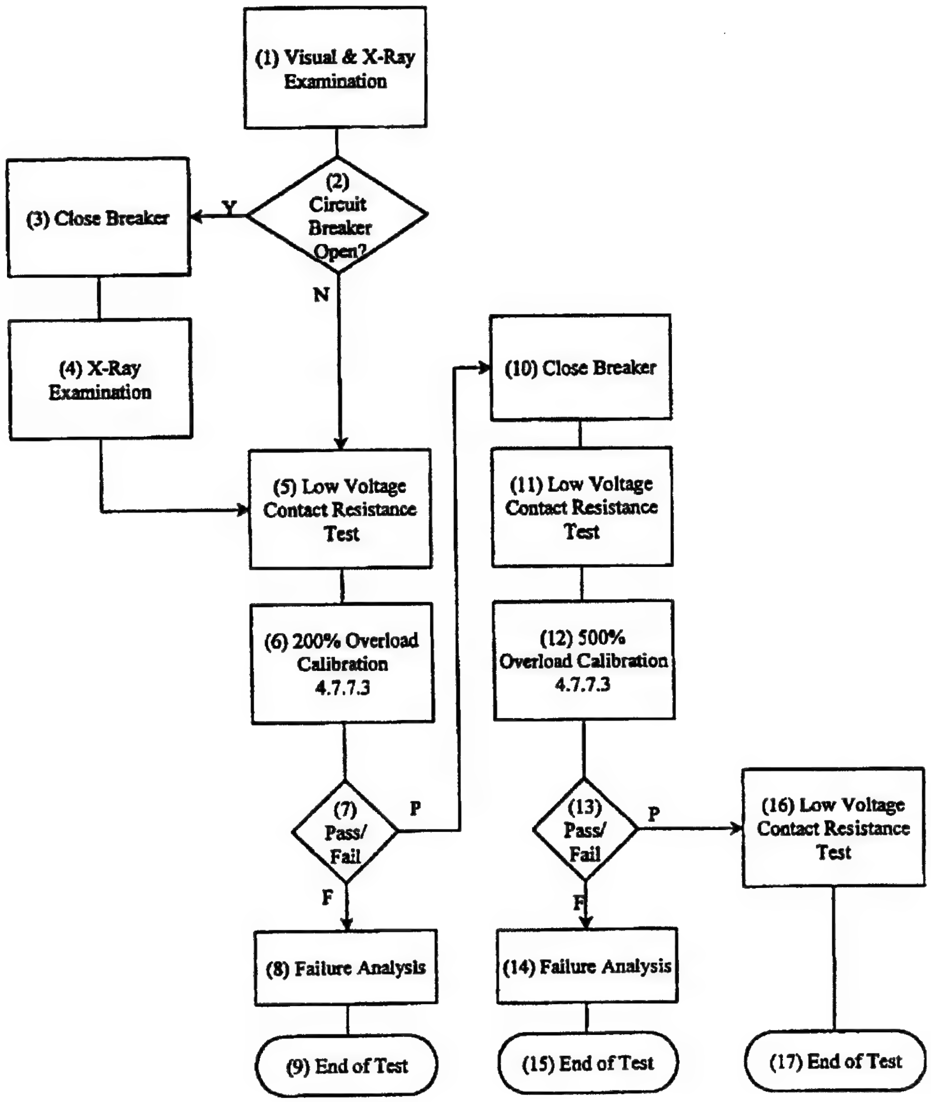
Page

Attachment 2

"Test Process Number 1"

from

FAA
"Research Plan for the
Evaluation of Age Related Degradation
of Single and Three Phase Circuit Breakers"


(1) Visual & X-Ray Examination
(2) Circuit Breaker Open?
Y
N
(3) Close Breaker
(4) X-Ray Examination
(5) Low Voltage Contact Resistance Test
(6) 200% Overload Calibration 4.7.7.3
(7) Pass/ Fail
P
F
(8) Failure Analysis
(9) End of Test
(10) Close Breaker
(11) Low Voltage Contact Resistance Test
(12) 500% Overload Calibration 4.7.7.3
(13) Pass/ Fail
P
F
(14) Failure Analysis
(15) End of Test
(16) Low Voltage Contact Resistance Test
(17) End of Test

TEST PROCESS NUMBER 1 FLOWCHART BLOCK DEFINITIONS

The chart above contains the Test Process Number 1 Flowchart. The flowchart illustrates the sequence of tests to be performed on the breakers designated for test. Each block in the flowchart is numbered. Complete descriptions of each block are provided below. To avoid repetition, blocks containing the same process are grouped together.

Block 1: **Visual & X-Ray Examination**

MIL-C-5809 Test Number: NA

Special Instructions: Each circuit breaker shall be examined visually and radiographically to record the initial condition of the breaker. Each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 2: **Circuit Breaker Open (Y/N)**

MIL-C-5809 Test Number: NA

Special Instructions: Record the state of the circuit breaker as either OPEN or CLOSED. If OPEN proceed to block 3. If CLOSED proceed to block 5. Do not change the state of the breaker.

Block 3, 10: **Close Breaker**

MIL-C-5809 Test Number:

Special Instructions: Breaker shall only be closed once. DO NOT cycle the breaker.

Block 4: **X-Ray Examination**

MIL-C-5809 Test Number:

Special Instructions: Generally, each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 5, 11, 16: **Low Voltage Contact Resistance Test**

MIL-C-5809 Test Number: 4.7.17.1 (see special instructions)
Special Instructions: 4.7.17.1 is normally performed in conjunction with Moisture Resistance tests (4.7.17). Moisture resistance is not part of this evaluation. However, the low voltage contact resistance measurement procedures described in 4.7.17.1 will be followed with the following deviations. Each CB will be operated in a circuit containing a dc resistive load of 200 milliamps at 26 ±2 volts. In series with the load shall be a manually operated switch (not the CB) to control power on/off. The contact resistance (specified as millivolt drop) shall be computed by averaging the result of 10 measurements. Each measurement shall be taken after a consecutive switch closure. All measurements shall be made across the CB external electrical terminals. (Note: The circuit breaker shall not be exercised on/off during this test) Soak (no load) at ambient for one-hour minimum before test.

Block 6: **200% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 200% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 7: <u>Pass/fail (200% Overload Calibration)</u>

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 8: <u>Failure Analysis (200% Overload Calibration)</u>

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 6 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 55 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 12: <u>500% Overload Calibration</u>

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 500% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 13: <u>Pass/fail (500% Overload Calibration)</u>

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 14: <u>Failure Analysis (500% Overload Calibration)</u>

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 59 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after

each of the five-off/on cycles. After the cycling process is complete, test 59 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 17: **End of Test**

MIL-C-5809 Test Number: NA

Special Instructions: Safely store the CB in a suitable container that will protect the CB from physical or chemical damage. Insure that the breaker is properly labeled. Store the CB in its end of test state. Do not close or open the CB switch, or manipulate the CB in any way. If the circuit breaker has been disassembled, collect and properly store all remaining parts.

DATE 9/7/01	MECHANICAL PRODUCTS FAILURE ANALYSIS REPORT	REPORT # 848
PART NUMBER 700-013-5	CUSTOMER FAA - RAYTHEON TECHNICAL SERVICES	S/N EE191
PART NAME CIRCUIT BREAKER	CUSTOMER PART NUMBER BACC18R5B	FILE CODE ja0907-3.far
TESTING BY DEPARTMENT 97 & 98	ANALYSIS AND/OR TEARDOWN BY DEPT. 97	CORRECTIVE ACTION BY DEPT.

STATEMENT OF DISCREPANCY

One MP P/N 700-013-5 (5 amp), BACC18R5B circuit breaker, stamped with a date code of the 50th week of 1973, was returned to Mechanical Products for analysis on 9/6/01 by Ron Peterson, Raytheon Technical Services, as part of the ongoing Federal Aviation Administration's "Evaluation of Age Related Degradation of Circuit Breakers" project. This breaker appeared to have been marked on one side with a felt pen as "EE191".

The documentation received at MP pertaining to unit "EE191" (Attachment 1) indicated Raytheon had subjected unit "EE191" to "Test Process Number 1" of the FAA's "Research Plan for the Evaluation of Age Related Degradation of Single and Three Phase Circuit Breakers" (Attachment 2). This documentation listed "EE191" as having been subjected to the "Low Voltage Contact Resistance Test" with an average voltage drop (over five runs) of 8.08 mV at 200 mA. It also listed "EE191" as having been subjected to the "Repeat 200% Overload Calibration Test" with a "Maximum Voltage Drop" of 168 mV, a "Maximum Temperature Rise" of 1°C, and an "Actual Trip Time" of 13.5 seconds. The "Results" column listed the unit as "fail", presumably based on the 13.5 sec. trip time being below the 15 second minimum specification limit (previously provided to Raytheon by Mechanical Products, based on Boeing Part Standard BACC18R5B).

ANALYSIS

Visual Examination

The breaker was externally examined. There was both terminal and mounting hardware attached to the breaker, presumably the hardware that was used in the aircraft application. Mechanical Products' Final Inspection and Functional Test department stamps were visible on the breaker case. These stamps, as well as the original part number stamping, Mechanical Products name, and the felt pen ID applied prior to receipt by MP are shown in the photographs of Figure 1.

It was noted that the external surfaces of the breaker were very clean (as compared to others field units of similar age which have been examined by MP). However, the ampere rating on the button ("5") was covered with grime and barely visible. This grime layer also appeared on the top side of the button (with respect to the rating stamp) but did not appear on the trip indicator. The terminals were thinly coated with a black substance, primarily on the screw head side. There was some dust and grime on the terminal screws and a thin layer of gray grime on parts of the case (which could be easily removed). The mounting bushing was a dark metallic gray color (rather than black).

Radiographs were taken in the "open" condition as received (Figure 2). No anomalies were noted.

"Block 8" Testing

The breaker was then tested according to the requirements of "Block 8 - Failure Analysis (200% Overload Calibration)" of the FAA's "Research Plan for ... Circuit Breakers". During the first on/off cycle radiographs were taken of the breaker in the "closed" condition (Figure 3). The low voltage contact resistance measurements were as follows:

12.9 mV (taken prior to cycling)
11.1 (after first cycle)
18.9 (after second cycle)
26.5 (after third cycle)
13.8 (after fourth cycle)
27.5 (after fifth cycle)

The 200% overload test results were as follows:

200% trip time (sec.)	Max. voltage drop (mV)	Terminal temperature rise (°C)
16.3	408	3

Dielectric Test

The dielectric tests of MIL-C-5809, paragraph 4.7.2 were performed with the following results (1500VAC for 1 minute):

		Leakage
CB open:	Line terminal to Load terminal	2 uA
	Line terminal to mounting sleeve	4 uA
	Load terminal to mounting sleeve	3 uA
CB closed:	Line/load terminals to mounting	5 uA

These values are within specification and well below the maximum specification of 1 mA. There was no evidence of breakdown, flashover or arcing.

Operating Force

The operating force tests of MIL-C-5809, paragraph 4.7.6 were performed 3 times with the following results:

Pullout	Reset	
6.0	6.5	pounds
6.5	7.0	
6.4	6.9	

These values are within specification (2 to 8 pounds pullout and 4 to 12 pounds reset).

Voltage Drop

The voltage drop across the breaker was measured three times at 100% of rated current per MIL-C-5809, paragraph 4.7.19 with the following results:

Voltage Drop	
196	mV
191	
191	

Although there are no maximum voltage drop limits specified for a BACC18R5B breaker, the results of this test are well within the 0.250 volt maximum specified for a 5 amp rated MS25244 breaker (MP 700-001-5).

200% Overload, Min/Max Ultimate Trip

Five 200% overload trip tests were performed per MIL-C-5809, paragraph 4.7.7.3; five 138% maximum limit of ultimate trip tests were performed per MIL-C-5809, paragraph 4.7.7.2; and five 115% minimum limit of ultimate trip tests (breaker must hold closed) were performed per MIL-C-5809, paragraph 4.7.7.1 with following results (time in seconds):

200%	138%	115%
20.8	121	NT
21.5	121	NT
16.7	120	NT
18.6	200	NT
19.7	196	NT

(Note: "NT" indicates breaker did not trip during test; for the 115% hold tests temperature monitoring was not performed)

All tests results are within specification. The specification requires the breaker to hold closed without tripping for the duration of the 115% minimum limit of ultimate trip test.

Internal Examination

The breaker was disassembled and examined. There were a small number of tiny black flakes loose within the case cavity. The contacts showed slight surface damage and there was minor discoloration of the case near the contacts, consistent with the breaker having been cycled under load or having tripped under overloads of less than short circuit conditions. There was some wear to the electrical (bimetal) latch. There was a normal amount of lubricant present on the button latch rollers. No obvious anomalies were noted.

Due to time constraints imposed for submission of this report, additional testing and analysis were not performed.

CONCLUSIONS

The low voltage contact resistance, voltage drop, operating force, 200% overload trip, 138% trip, and 115% hold test results were all within specified limits. The results were all very similar to results of tests on 5 amp MP 700 Series circuit breakers built within the year 2001. All tests were performed to the requirements of MIL-C-5809 and BACC18R unless otherwise noted.

The field history of the breaker identified as "EE191" was not available at the time of this analysis.

The 200% overload trip test performed at Raytheon may have been the first time this breaker was required to open a circuit in response to an overload condition since it left Mechanical Products approximately 28 years ago. The number of manual cycles since initial installation also was not known.

The 200% overload trip time experienced at Raytheon was only 1.5 seconds under the specified 15 second minimum (less than 4% of the allowable 15 to 55 second trip range). Multiple 200% overload tests at Mechanical Products did not repeat the failure seen at Raytheon. The breaker also passed five 138% maximum ultimate trip tests and five 115% minimum ultimate trip tests at Mechanical Products.

Examination of the internal mechanism did not appear to indicate the breaker had been electrically or manually cycled much beyond the endurance limits specified in BACC18R. There were no indications that the breaker had been exposed to high current interruption or severe contamination.

The additional testing without failures indicates this breaker is probably within specification. The slightly low 200% trip time during the Raytheon testing could be the result of not having exercised the electrical trip portion of the mechanism in a very long time. As noted previously, the functional history of this breaker during the approximately 28 years since it left Mechanical Products was not available.

CORRECTIVE ACTION

None requested or required.

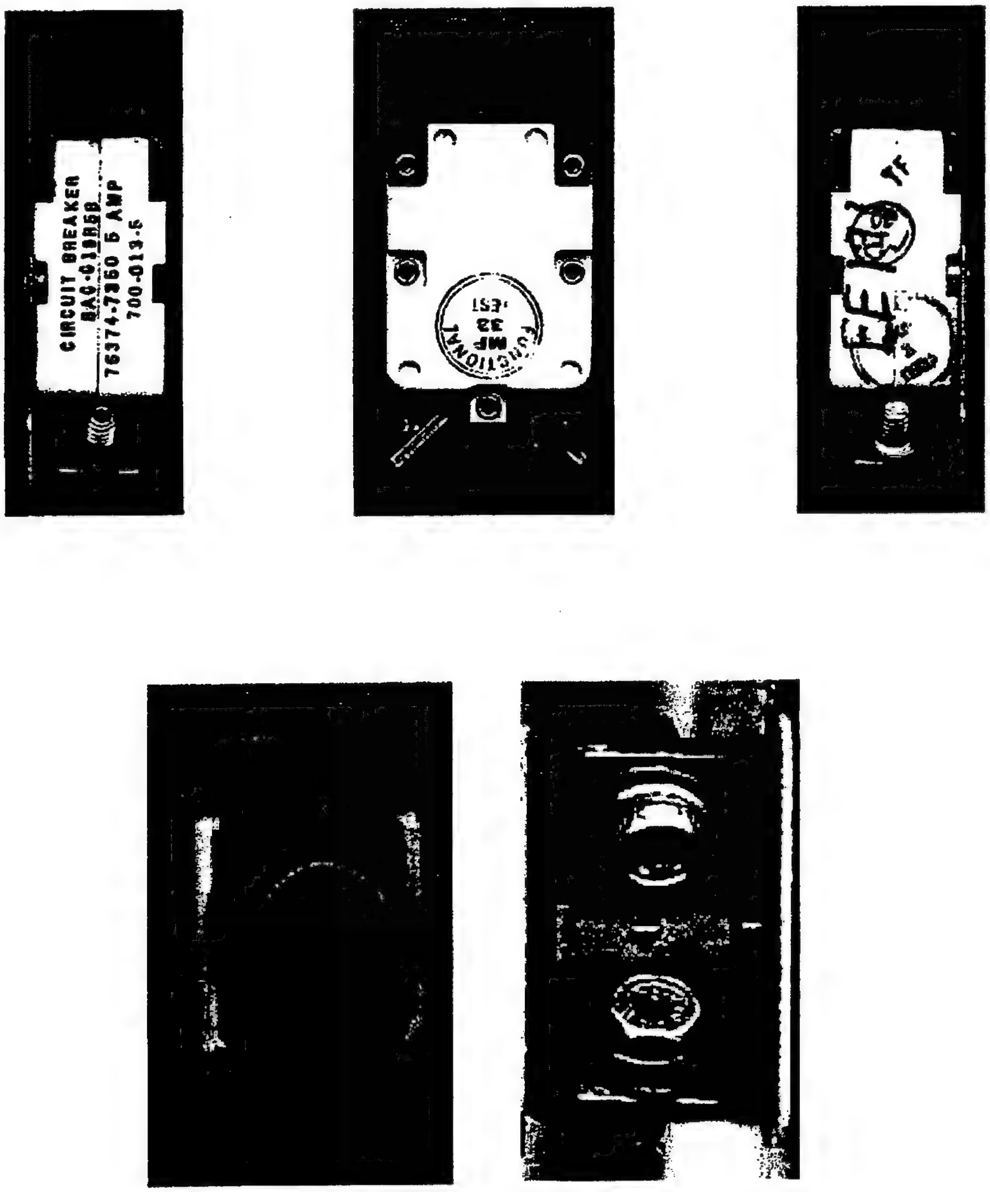


Figure 1.
Exterior of circuit breaker "EE191".

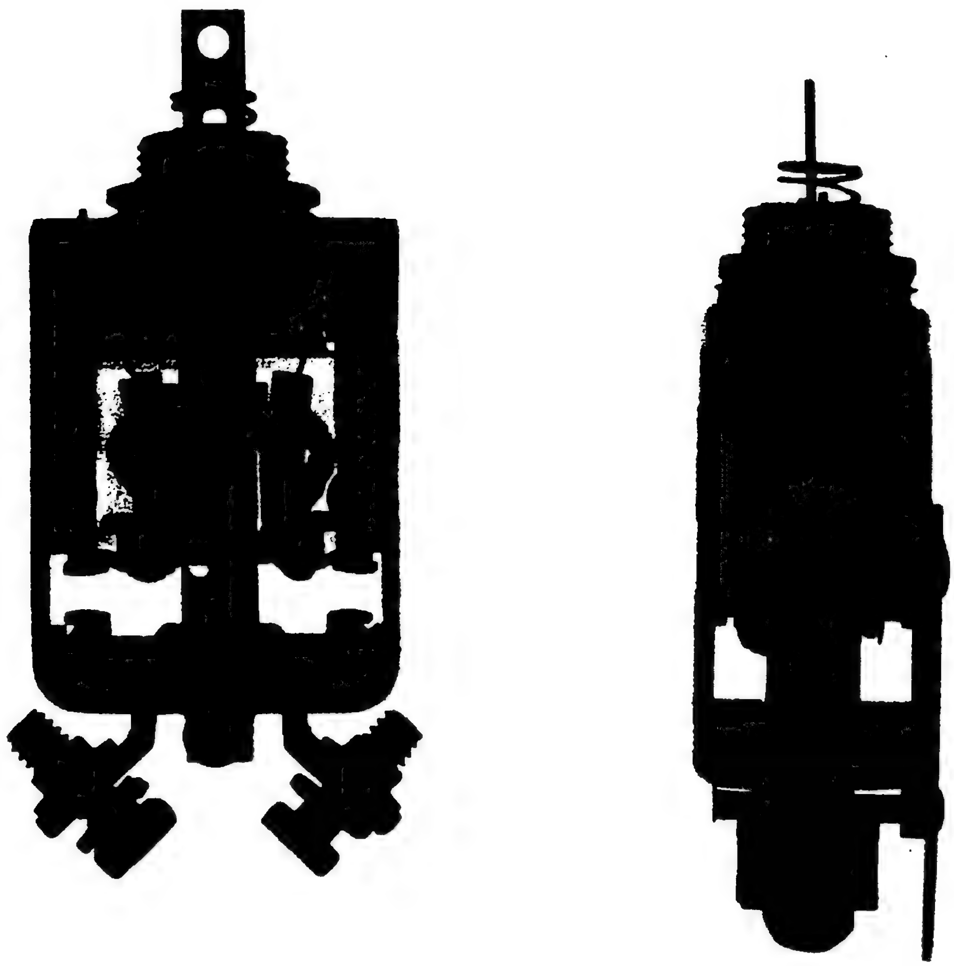


Figure 2.
Radiograph of breaker "EE191" in the open (unlatched) position as received.

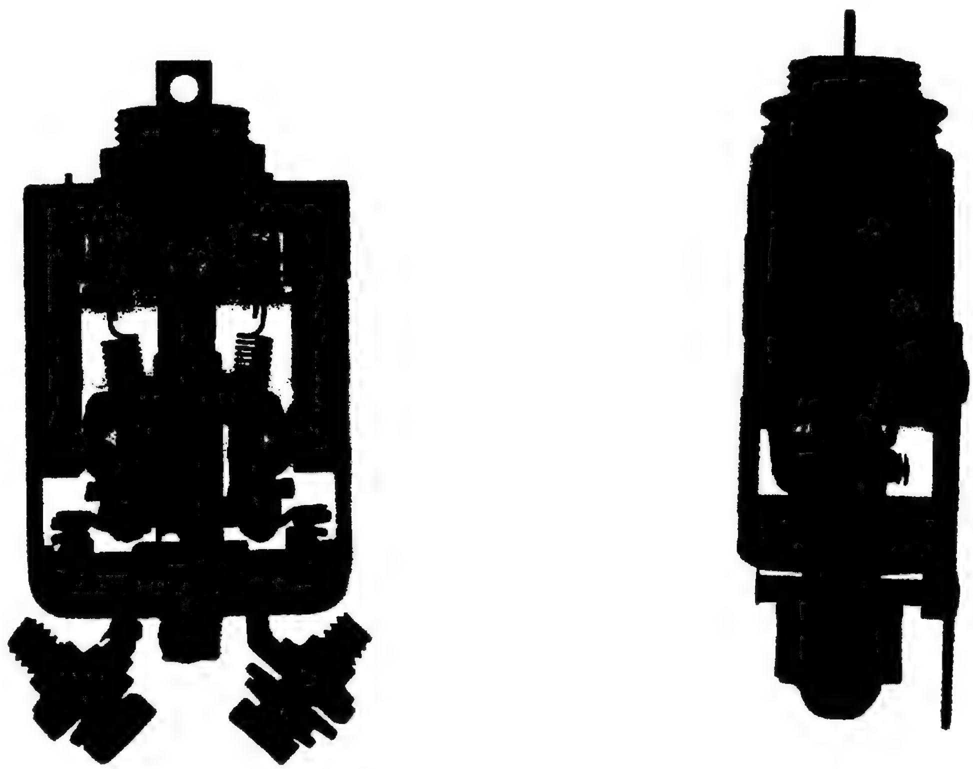


Figure 3.
Radiograph of breaker "EE191" in the closed (latched) position.

Attachment 1

Documentation received for sample "EE191"

Date: 9/5/01

To: Mechanical Products Inc.
Attn: James C. Allison
1824 River Street
Jackson, MI 49202

From: Raytheon Technical Services Company
Attn: Ronnie Peterson, M/S 37
6125 East 21ST Street
Indianapolis, IN 46219-2058

In-closed are the failed samples that occurred during our FAA testing on circuit breakers that came from aged aircraft.

You are requested to perform a failure analysis on the breakers per your agreement with the FAA representative Mr. Rob Pappas.

Please send your report by 9/12/01, so that it can be added to the FAA report to be provided by RTSC.

Please provide a separate report for each failure and designate your report by the number specified for the sample.

Regards

Ron

Ron

TEST PROCEDURE #4000G-FAA DATE(last revised) 8/30/01

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
TEST LABORATORY DATA SHEET

Sample Number	Observation Notes	Report Number	x-ray wide & narrow Provid	X-ray Button View Provid	Repeat Test Compte	LVCR Info Sent	Date Sent	Date Recv	Shipping Information
4D213	1	4D213P1BS			*	*			
EE312		EE312P1B	✓	✓	✓	✓	9/5		
EE191		EE191P1B	✓	✓	✓	✓	9/5		
GE200		GE200P1B			✓				

OBSERVATIONS: 1* CANNOT PERFORM LVCR, BREAKER WILL NOT STAY CLOSED. Notice Problem at block 5

Page ______

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
LABORATORY TEST DATA SHEET

Test Low Voltage Contact Resistance	Project Number 50-20-011	Date 8/30/01	Tested By GSA
Test Equipment H/P 6034A H/P 6032A Keithley 197 Keithley 197	Calibration Number 36529 40568 35205	Calibration Due 1/9/04 12/22/02 12/22/02	Specification FAA & MIL-C-5809
Process #: 1 Block #: 8	Test Temperature: 24C Soak Temperature: 24C	Test Paragraphs: Met: 4.7.17.1 & FAA Test Plan	Test Parameters Voltage (Open Circuit Volts DC): 26 ±2V

	MEASURED VOLTAGE DROP (mV)	cycled 1	cycled 2	cycled 3								CURRENT
SAMPLE NUMBER	READING #1	READING #2	READING #3	READING #4	READING #5	READING #6	READING #7	READING #8	READING #9	READING #10	READING AVERAGE	Last Reading (MILLIAMP)
EE312	327.78	195.523	302.72	312.14	315.82							200
EE191	8.043	7.967	7.927	7.915	8.570							200
GE200	13.177	9.169	8.717	8.514	12.073							200
HD213	will	not	STAY	CLOS	ED).	(not	tested	Notice	Problem	at block	5)	

COMMENTS:

Page

TEST PROCEDURE #3008C-FAA

DATE(last revised) 9/5/01

RAYTHEON TECHNICAL SERVICES COMPANY
INTERCONNECTIONS ENGINEERING
LABORATORY TEST DATA SHEET

	Project Number 50-20-011	Date 9/5/01	Tested By [illegible]
Test Equipment Munro Q/C-20 Omega CM-400	Calibration Number 45585 39650	Calibration Due 1/8/02 8/20/02	Specification MIL-C-5809
Test Repeat 200% Overload Calibration	Test Paragraphs Req: 3.7.4 Met: 4.7.4.3		Test Process #: 1 Process Block #: 8 Ambient Temp: 26°C

SAMPLE NUMBER	CURRENT RATING (A)	MAX VOLTAGE DROP (MV)	MAX TEMP RISE (C)	REQUIRED TRIP TIME (S)	ACTUAL TRIP TIME (S)	RESULTS PASS/ FAIL
EE191	5	168	1	15-55	13.5	FAIL
GE200	5	13.5	2	15-55	13.9	FAIL
E 3/12 ~~3/12~~	3	0	2	~~30~~ ~~5~~ 20	0	FAIL

COMMENTS: ________

Page ______

-WX2P1

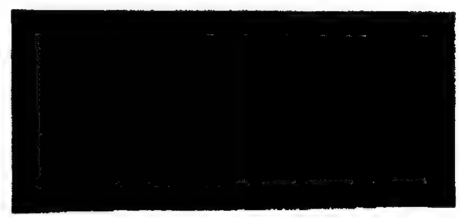
↓

LJ316

-BX1P8

↓

EE191



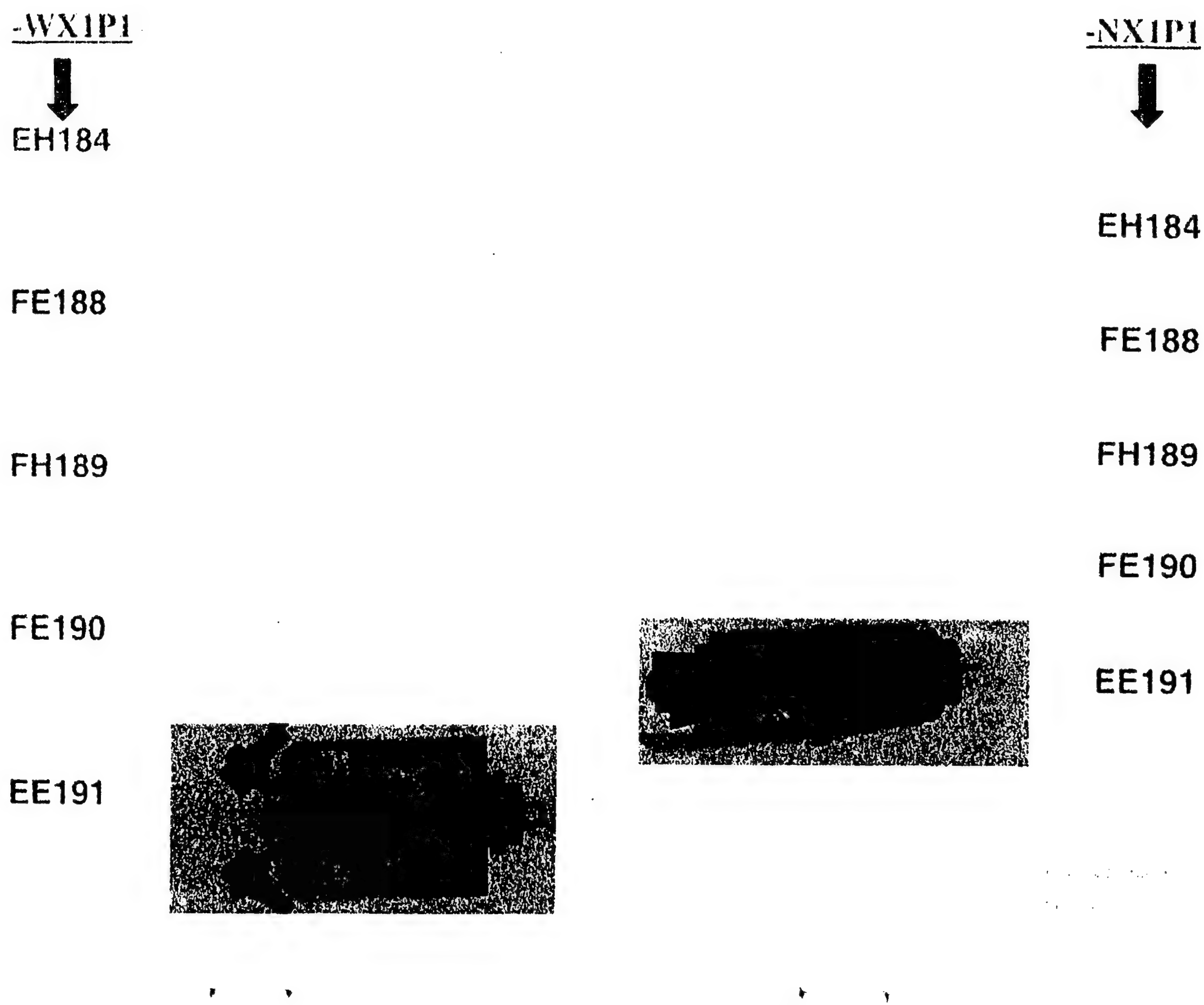
-NX2P1

↓

LJ316

Process 2: (Box 1)

Line 294

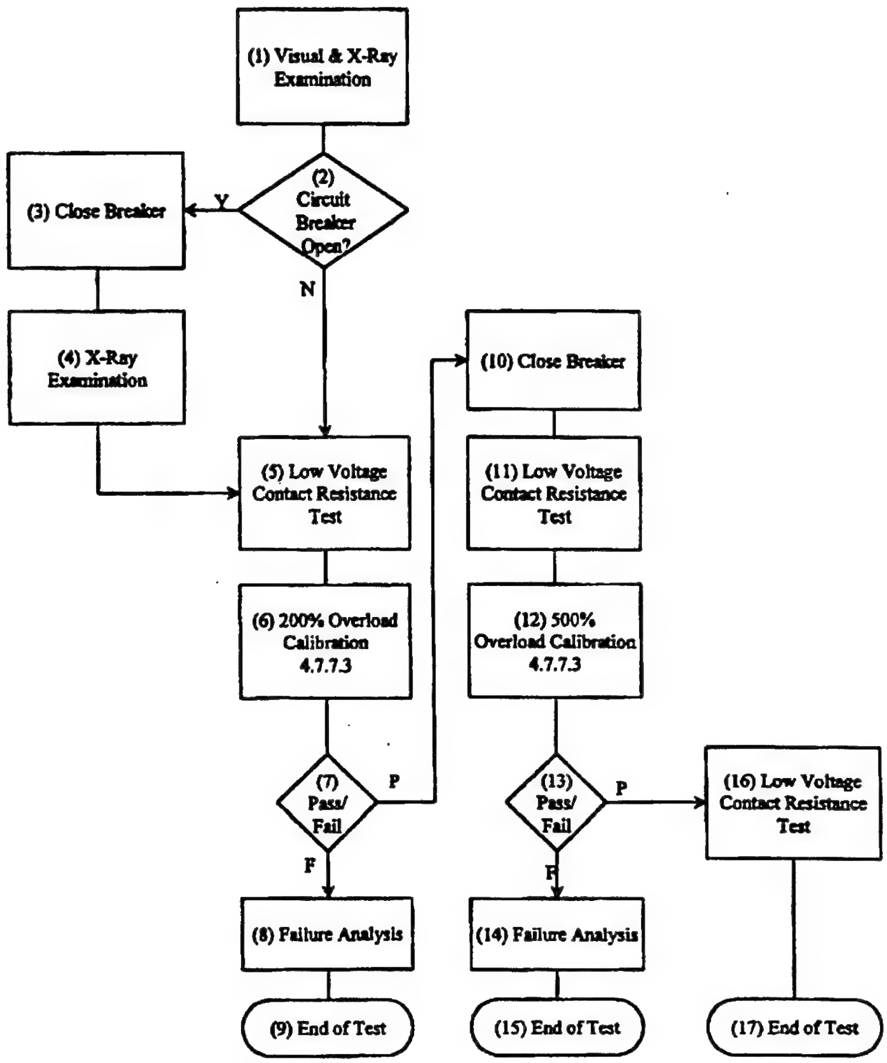

-WX1P1
EH184
FE188
FH189
FE190
EE191
-NX1P1
EH184
FE188
FH189
FE190
EE191

Attachment 2

"Test Process Number 1"

from

FAA
"Research Plan for the
Evaluation of Age Related Degradation
of Single and Three Phase Circuit Breakers"


(1) Visual & X-Ray Examination
(2) Circuit Breaker Open?
Y
N
(3) Close Breaker
(4) X-Ray Examination
(5) Low Voltage Contact Resistance Test
(6) 200% Overload Calibration 4.7.7.3
(7) Pass/ Fail
P
F
(8) Failure Analysis
(9) End of Test
(10) Close Breaker
(11) Low Voltage Contact Resistance Test
(12) 500% Overload Calibration 4.7.7.3
(13) Pass/ Fail
P
F
(14) Failure Analysis
(15) End of Test
(16) Low Voltage Contact Resistance Test
(17) End of Test

TEST PROCESS NUMBER 1 FLOWCHART BLOCK DEFINITIONS

The chart above contains the Test Process Number 1 Flowchart. The flowchart illustrates the sequence of tests to be performed on the breakers designated for test. Each block in the flowchart is numbered. Complete descriptions of each block are provided below. To avoid repetition, blocks containing the same process are grouped together.

Block 1: **Visual & X-Ray Examination**

MIL-C-5809 Test Number: NA

Special Instructions: Each circuit breaker shall be examined visually and radiographically to record the initial condition of the breaker. Each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 2: **Circuit Breaker Open (Y/N)**

MIL-C-5809 Test Number: NA

Special Instructions: Record the state of the circuit breaker as either OPEN or CLOSED. If OPEN proceed to block 3. If CLOSED proceed to block 5. Do not change the state of the breaker.

Block 3, 10: **Close Breaker**

MIL-C-5809 Test Number:

Special Instructions: Breaker shall only be closed once. DO NOT cycle the breaker.

Block 4: **X-Ray Examination**

MIL-C-5809 Test Number:

Special Instructions: Generally, each sample will be x-rayed once in each axis. Check with OEM possible circuit breaker type specific x-ray requirements.

Block 5, 11, 16: **Low Voltage Contact Resistance Test**

MIL-C-5809 Test Number: 4.7.17.1 (see special instructions)
Special Instructions: 4.7.17.1 is normally performed in conjunction with Moisture Resistance tests (4.7.17). Moisture resistance is not part of this evaluation. However, the low voltage contact resistance measurement procedures described in 4.7.17.1 will be followed with the following deviations. Each CB will be operated in a circuit containing a dc resistive load of 200 milliamps at 26 ±2 volts. In series with the load shall be a manually operated switch (not the CB) to control power on/off. The contact resistance (specified as millivolt drop) shall be computed by averaging the result of 10 measurements. Each measurement shall be taken after a consecutive switch closure. All measurements shall be made across the CB external electrical terminals. (Note: The circuit breaker shall not be exercised on/off during this test) Soak (no load) at ambient for one-hour minimum before test.

Block 6: **200% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 200% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 7: **Pass/fail (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 8: **Failure Analysis (200% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 6 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after each of the five-off/on cycles. After the cycling process is complete, test 55 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 12: **500% Overload Calibration**

MIL-C-5809 Test Number: 4.7.7.3
Special Instructions: Test at 500% of rated current only. Do not test at higher currents. Soak (no load) at ambient for one-hour minimum before test, breaker in the open position, if possible. Do not open the breaker if it is already in a closed position. Voltage drop from circuit breaker terminal-to-terminal will be monitored at all times. The temperature rise of the breaker terminals shall be obtained by the use of a suitable thermocouple.

Block 13: **Pass/fail (500% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: NA

Block 14: **Failure Analysis (500% Overload Calibration)**

MIL-C-5809 Test Number: 4.7.7.3

Special Instructions: As the first step in the failure analysis, the OEM will repeat test 59 after the breaker has been cycled off/on five times with no power applied. A low voltage contact resistance measurement will be obtained before the first and after

each of the five-off/on cycles. After the cycling process is complete, test 59 will be repeated. Regardless of the outcome of this test, a failure analysis will be performed to determine the cause of the first failure or both failures as applicable. The failure analysis will be conducted by the circuit breaker OEM. The OEM will follow approved, company standard operating procedures (SOP) to conduct the analysis. When the SOP is inadequate for the complete determination of the failure or degradation causal factors, it shall be supplemented with additional procedures necessary to do so. For example, such procedures might include chemical analysis, optical microscopy, electron microscopy, and others.

Block 17: **End of Test**

MIL-C-5809 Test Number: NA

Special Instructions: Safely store the CB in a suitable container that will protect the CB from physical or chemical damage. Insure that the breaker is properly labeled. Store the CB in its end of test state. Do not close or open the CB switch, or manipulate the CB in any way. If the circuit breaker has been disassembled, collect and properly store all remaining parts.

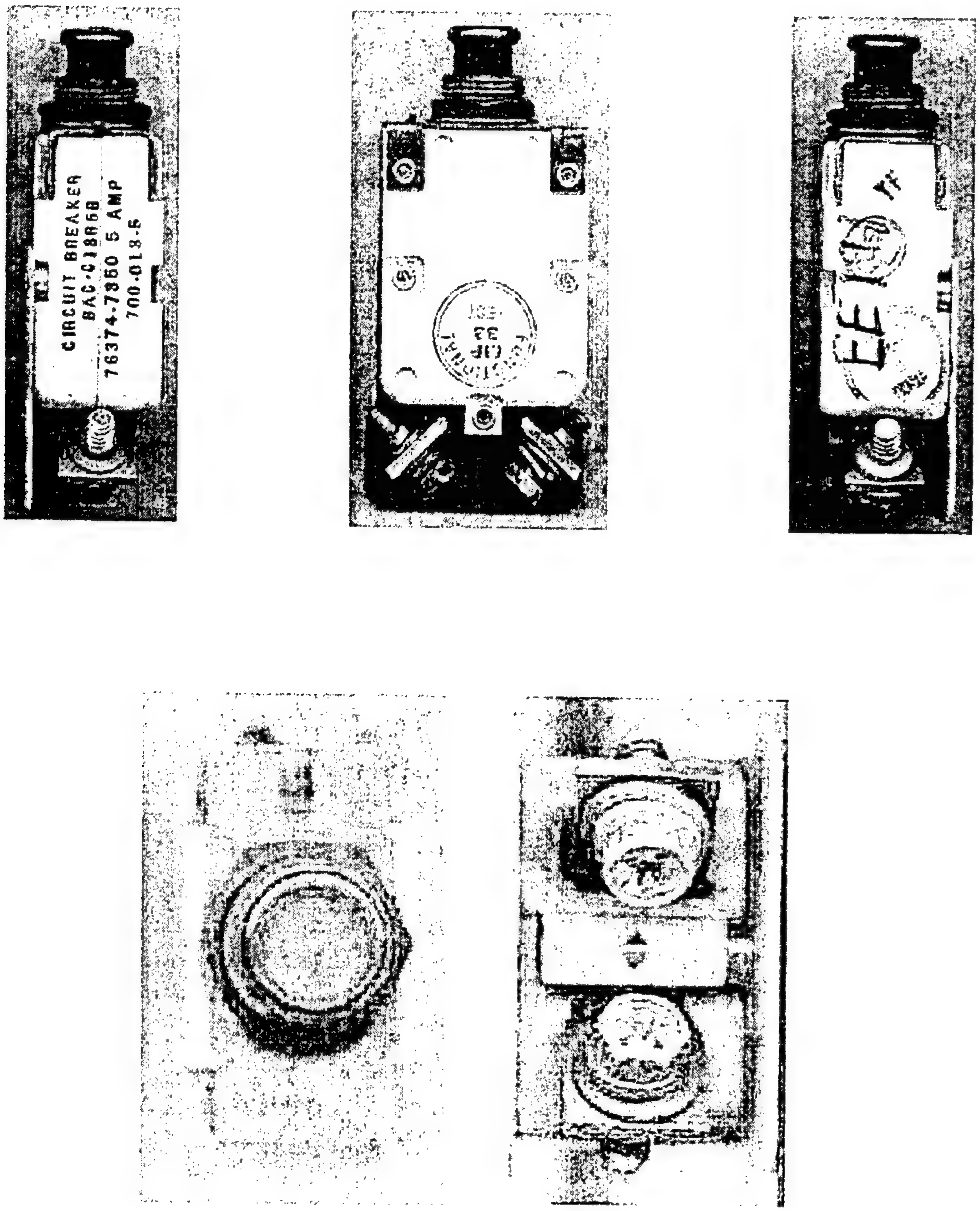


Figure 1.
Exterior of circuit breaker "EE191".

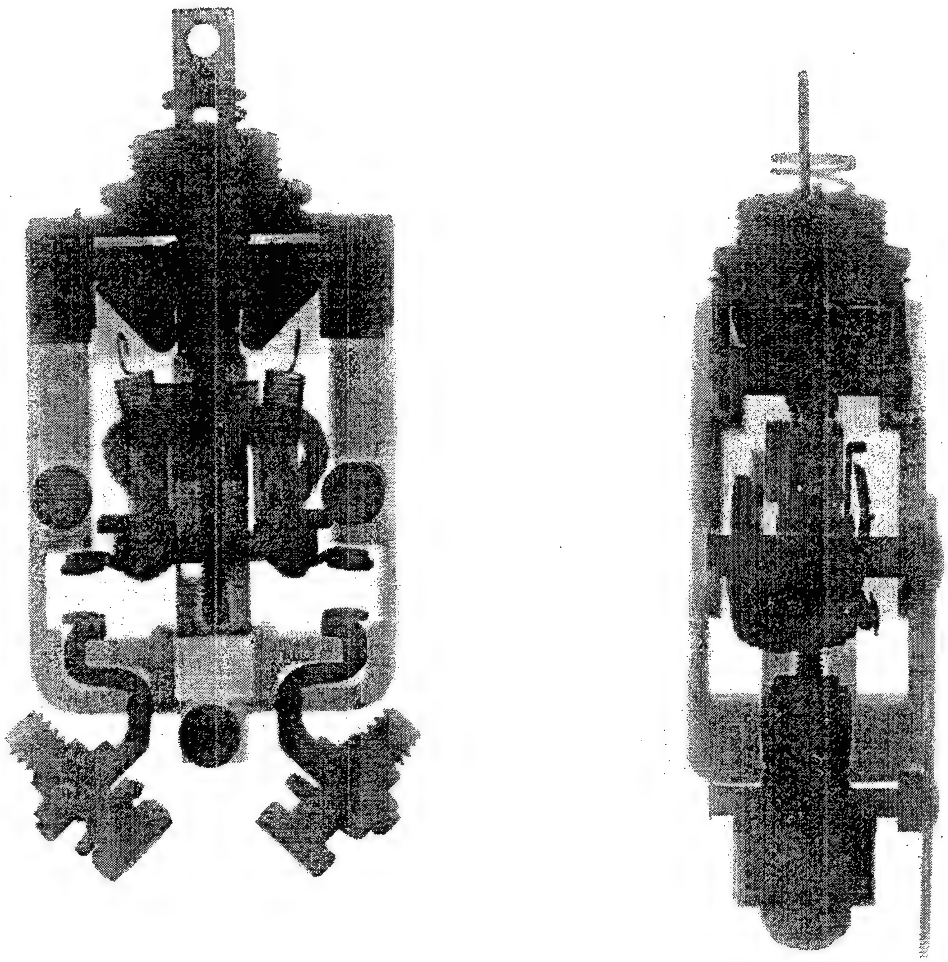


Figure 2.
Radiograph of breaker "EE191" in the open (unlatched) position as received.

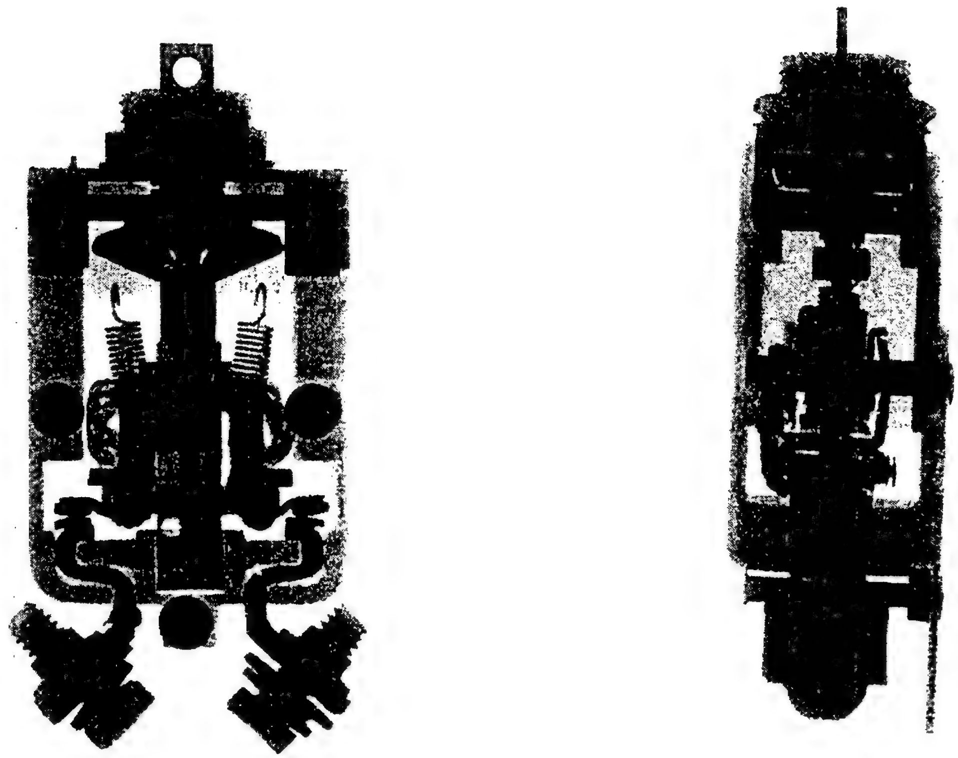


Figure 3.
Radiograph of breaker "EE191" in the closed (latched) position.

APPENDIX G—FAA AIRWORTHINESS ASSURANCE NONDESTRUCTIVE INSPECTION VALIDATION CENTER TEST PROCEDURE FOR CIRCUIT BREAKER FROM AGED AIRCRAFT

TEST PLAN

DRAFT

Aging Aircraft Circuit Breakers

Test Plan Revision: Revision 1, March 14, 2000

Approved: ______________________________ ________
Date

______________________________ ________
Date

______________________________ ________
Date

______________________________ ________
Date

09/06/2001

Contents

1.0 Purpose

This document specifies preliminary characterization testing that is to be performed on circuit breakers removed from aged aircraft. The testing objectives are to determine the condition of the breakers with respect to the manufacturers' original specifications, and identify the need for further research.

2.0 Description of parts to be furnished for testing

A total of 48 circuit breakers will be provided for testing. The breakers will be procured in 4 groups of 12 each. Each group shall consist of circuit breakers of the same rating and manufacturer. Together the four groups will represent three current ratings and if possible, at least 3 different manufacturers. The two groups with the same current rating will represent two different manufacturers. Refer to the table below for clarification.

Group	Rating (Illustration only)	Quantity	Manufacturer
1	5A	12	X
2	15A	12	Y
3	15A	12	Not Y
4	35A	12	Z

All circuit breakers will be removed from in-service or retired transport aircraft with over twenty years of operational service. Retired aircraft will have been out of service for no longer than 3 months at the time of removal. Each breaker will be delivered to Sandia National Laboratories with the following information: aircraft type, aircraft number, years and flight hours of a/c, circuit name and number, circuit breaker manufacturer name, circuit breaker setting (off, on, or known tripped) at time of removal from the aircraft. To the extent possible, breakers in each group will be selected from circuits representing a variety of load characteristics (lighting, motors/pumps, avionics, etc.). It is anticipated that all breakers will be of the panel-mount push-pull type, with terminals that utilize ring lug connections attached by screws.

Circuit breakers will be manipulated as little as possible during removal and shipping. Circuit breakers will be removed from the aircraft in the condition found (off, on, or tripped) and will not be exercised at any time prior to testing in the laboratory. At least 8 breakers in each group will be removed in the 'On' position.

3.0 Incoming and pretest inspection

Unpacking of the parts from the shipping container will be done carefully, and the parts will be handled in such a way that there is no change in the on-off condition of the breakers as received.

Parts will be visually inspected, and their condition as received will be documented. Documentation furnished with the breakers will be checked for the information described in Section 2..0. If the breakers are furnished still attached to panels, with wiring, the condition of the wiring and panels will be examined and documented. Any observed mechanical defects in the panels or wiring will be noted. Panel assemblies will be photographed with a digital camera.

Breakers will be removed from the panels, exercising care that breakers in the off position (pulled) are not inadvertently closed. The breakers will be labeled or marked as they are removed from the panels (or unpacked, if not attached to panels) to identify each breaker with the information supplied. The breakers will be visually inspected and the condition of each breaker documented. Any breaker having visual damage or other anomaly will be photographed. Condition of the terminal screws will be noted for each breaker (looseness, corrosion, thread or other damage). If the wiring is attached, any anomalies in the terminal lugs will be noted (poor crimp, sharp bends, corrosion, other). If the breakers are visually dirty or contaminated, they will not be cleaned until insulation resistance measurements are made as described below.

At least one breaker from each group will be radiographed. If there are open and closed breakers (as delivered) from each manufacturer, a sample of each will be radiographed. The radiographs will be inspected for mechanical anomalies.

4.0 Electrical Testing

4.1 Leakage resistance testing

Prior to beginning the test for proper operation, and before cleaning visibly dirty units, insulation resistance will be tested for each breaker by applying 500 V DC potential for one minute, using a suitable tester designed for the purpose, and noting the resistance, or noting current and calculating resistance. The measurement will be made between each terminal and the case mounting bushing for the closed breakers, and additionally between terminals for those breakers received in the open position. Breakers that display less than 10 megohms resistance terminal-to-case will be cleaned by wiping with dry cloth or paper wipes, taking care not to remove markings, and retested. Breakers that measure less than 1 megohm in any configuration will be removed from testing and disassembled for examination.

4.2 Pass/fail electrical testing

The breakers will be connected to automatic testers, open breakers closed, and electrical tests performed as follows, using an applied voltage of 2.5 V DC or less measured at the breaker terminals. The power supplies will have a current capability of at least 150% of the rating of the breaker. All data will be recorded digitally. All measured parameters will be scanned by the testers each 1 second, and the data recorded as specified below.

Test 1. Apply a current through the breaker of 100 mA for 5 minutes, and record the current and voltage drop across the terminals each 10 seconds. Calculate and record the time, current, voltage, and voltage/current ratio (resistance). If the resistance at the end of 5 minutes exceeds 10 ohms, terminate the test and document the failure. Electrically disconnect the breaker from the tester, and measure the resistance with an ohmmeter with leads attached in a manner that minimizes connection resistance, documenting the results. Reconnect the breaker to the tester, reapply 100 mA current, and cycle the breaker manually ten times, with the tester recording voltage, current, and resistance as above. Manual breaker cycling will be done using a gauge that measures force needed to actuate the breaker plunger. If the resistance measured after the mechanical cycling still exceeds 10 ohms, terminate the test and remove the breaker from the fixture, otherwise continue with Test 2.

Test 2. Ramp the applied current over a period of 1 minute from zero to 100% of the rating of the breaker. Hold this current for 1 hour, recording the time, current and voltage across the terminals each 5 minutes, or if there is a change of 2% or more in current or voltage. If the breaker opens during this test, terminate the test and remove the breaker from the fixture. If the rated current cannot be achieved with the 2.5 V power supply limit,.terminate the test and remove the breaker.

Test 3. If the breaker holds 100% rated current for 1 hour, continue the testing, ramping the current up by 2% of the breaker rating each 5 minutes to 138% of current rating. Hold at 138% rating for an additional 55 minutes. Time, current and voltage across the terminals will be recorded each 5 minutes, or if there is a change of 2% or more in current or voltage. If the breaker does not open during this time, terminate the test, and remove the breaker from the fixture.

4.3 Testing of failed units

1. Breakers that fail Test 1 will be disassembled and the interior mechanism and contacts examined and documented. The interior components and contacts will be photographed at the highest available magnification and resolution. Contacts and contact assemblies will be tested with an ohmmeter to attempt to locate the high resistance. Contact assemblies will be sent to a chemical testing laboratory for analysis of surface corrosion.

2. Any breaker that fails Test 2 will be disassembled and visually examined for mechanical damage or anomaly, particularly to the bimetallic contact strip. Results of the physical examination will be documented. Digital photographs will be taken of the parts

3. Breakers that fail Test 3 will be opened manually using a spring scale to measure the opening force required. The manual open and close cycle will be repeated ten times, recording the force needed for opening. The results will be compared with manufacturers specifications if available, and with measurements of a breaker of the same type, manufacturer, and current rating that passed Test 3. If the opening force is high compared with a properly functioning breaker, and remains high, the breaker will be disassembled and examined for mechanical failure or contamination. If the breaker has a manual opening force comparable to the properly operating breaker, the breaker will be returned to the electrical test fixture, and the electrical tests repeated. If the breaker then fails any of Tests 1, 2, or 3, testing will be terminated and the breaker disassembled for examination. If the breaker passes all tests, the breaker will then be disassembled and examined for contamination, particularly around the plunger. Disassembled breakers and parts will be photographed.

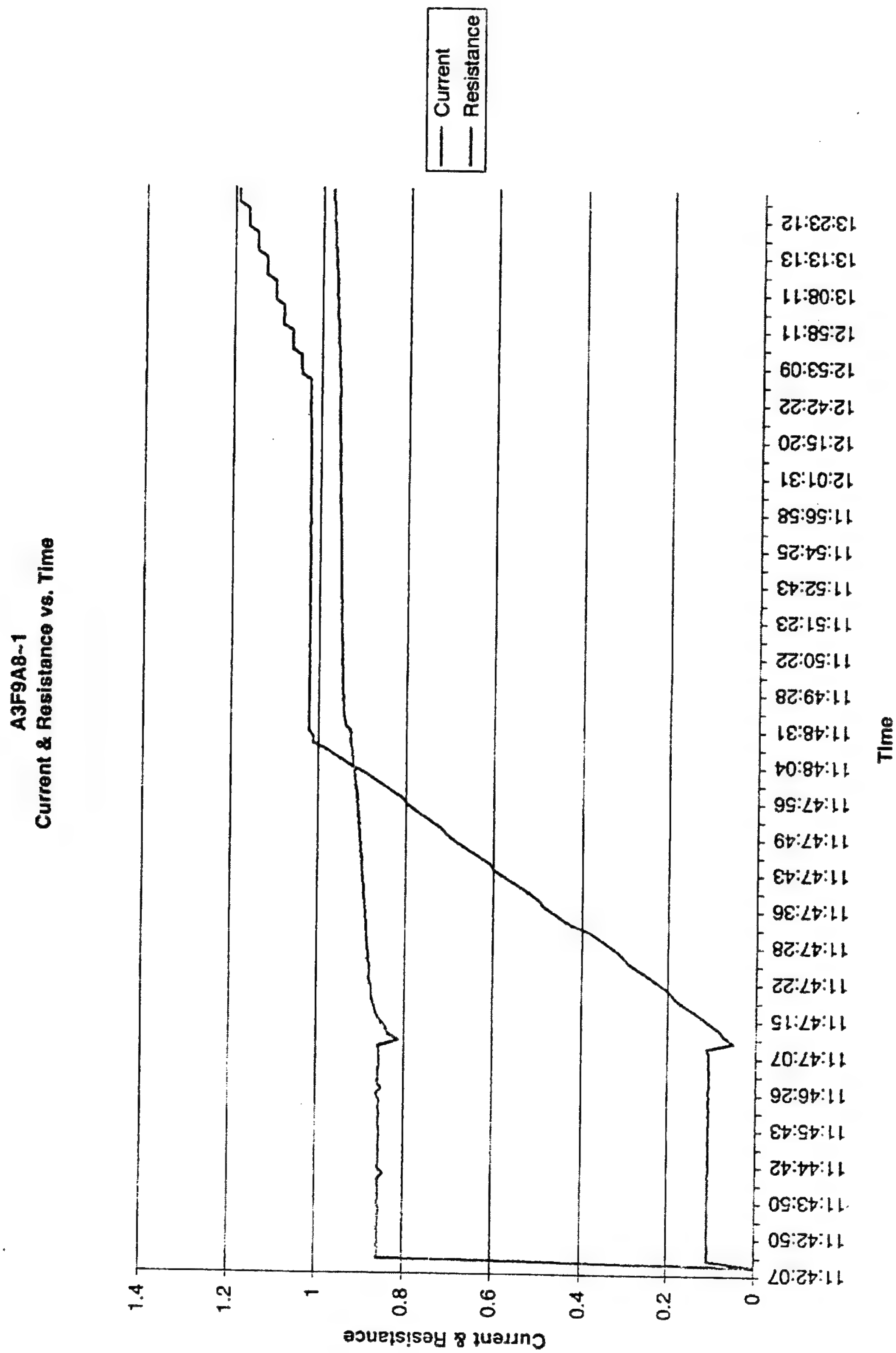
All disassembled breakers will be packaged separately in containers for possible later examination.

5.0 Reporting

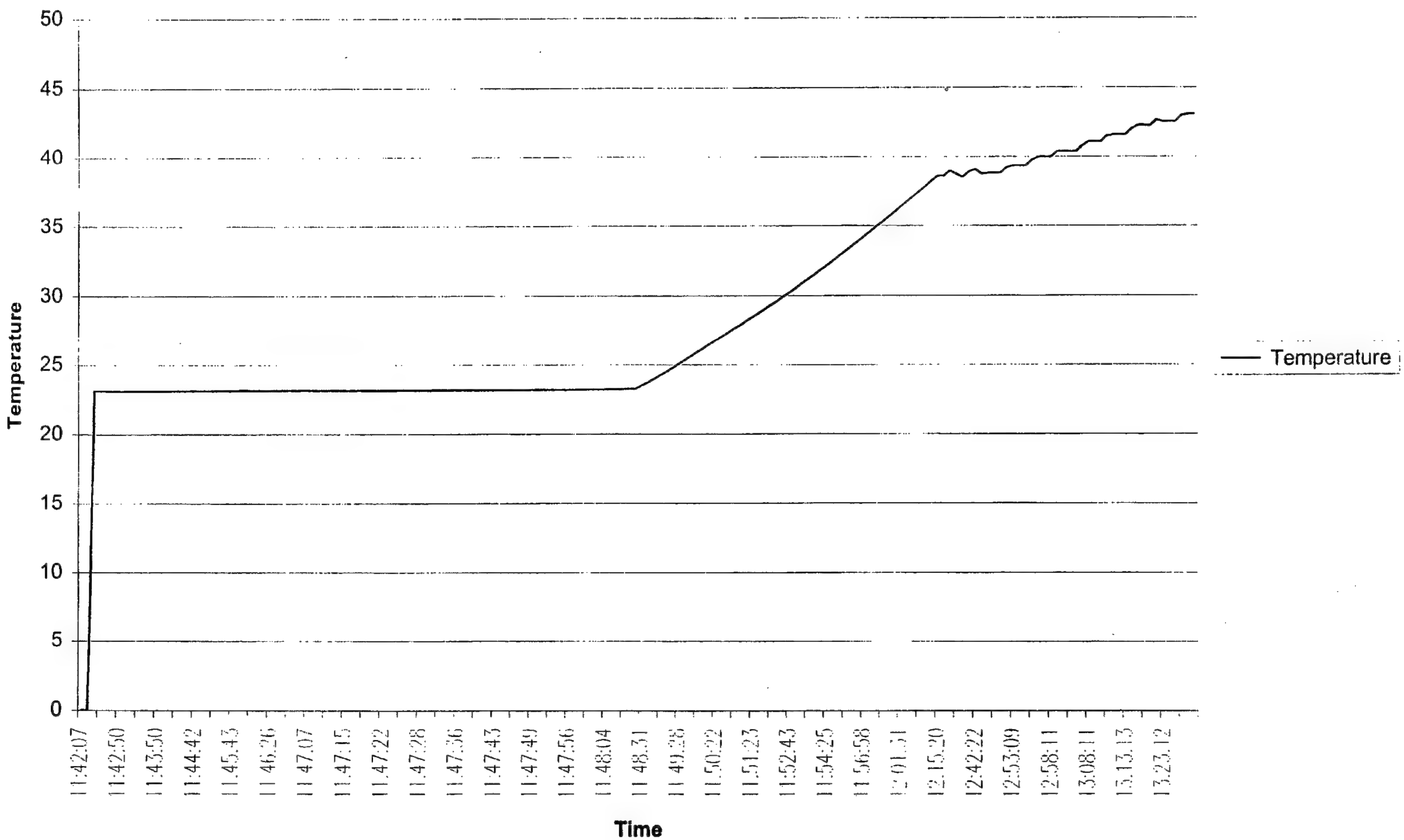
A report will be written describing the testing and results. Complete digital test data from the automatic testers will be supplied if desired in Excel spreadsheet format. Copies of logs of manually recorded test data (visual condition, manual resistance measurements) can be supplied on request. All digital photographs will be supplied electronically in JPEG format. Unless otherwise requested, digital information will be supplied on CDROM.

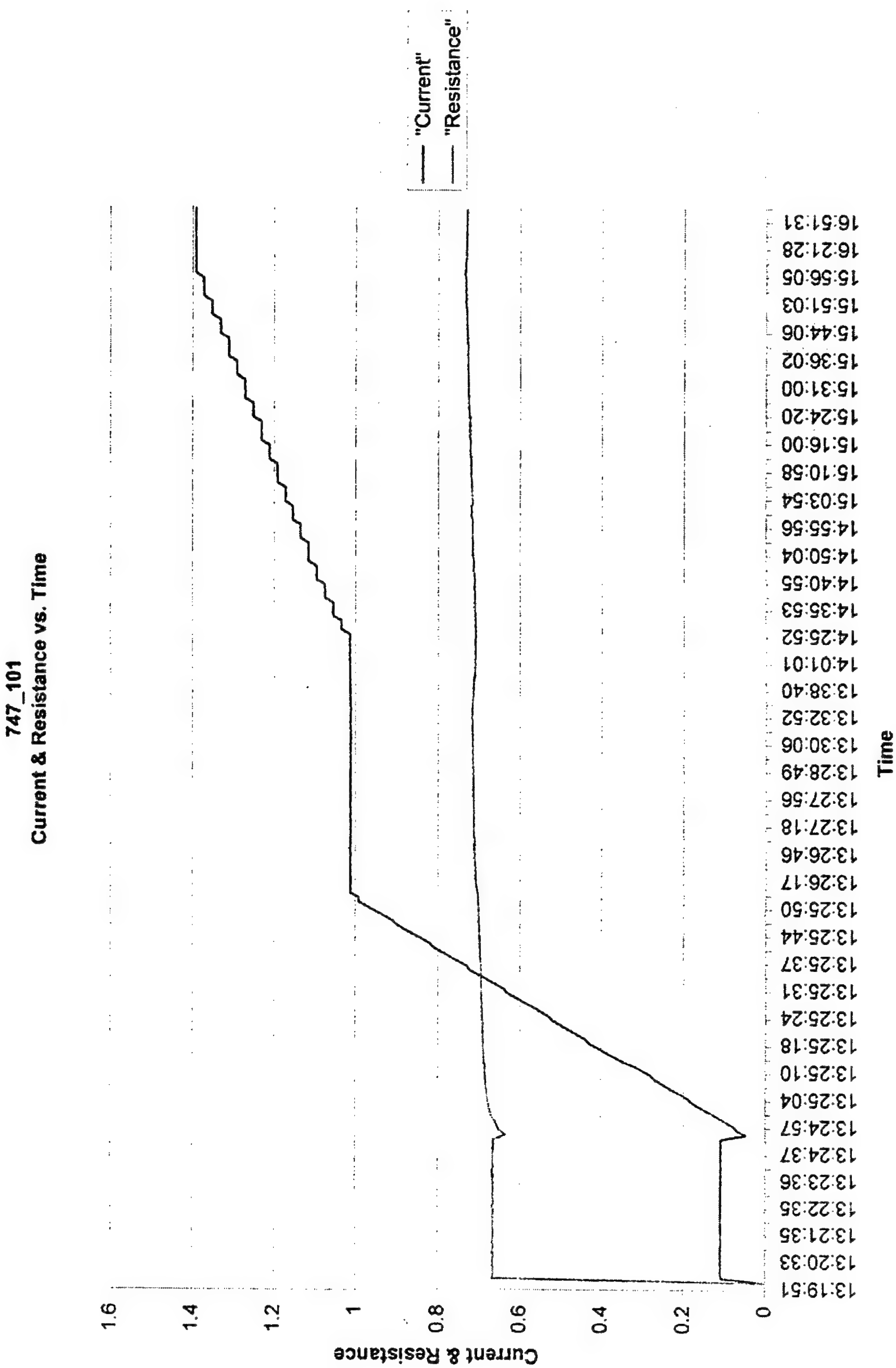
APPENDIX H—FAA AIRWORTHINESS ASSURANCE NONDESTRUCTIVE INSPECTION VALIDATION CENTER TEST RESULTS ON CIRCUIT BREAKERS REMOVED FROM AGED AIRCRAFT

H.1 CURRENT, RESISTANCE, AND TEMPERATURE RISE EXAMPLES.

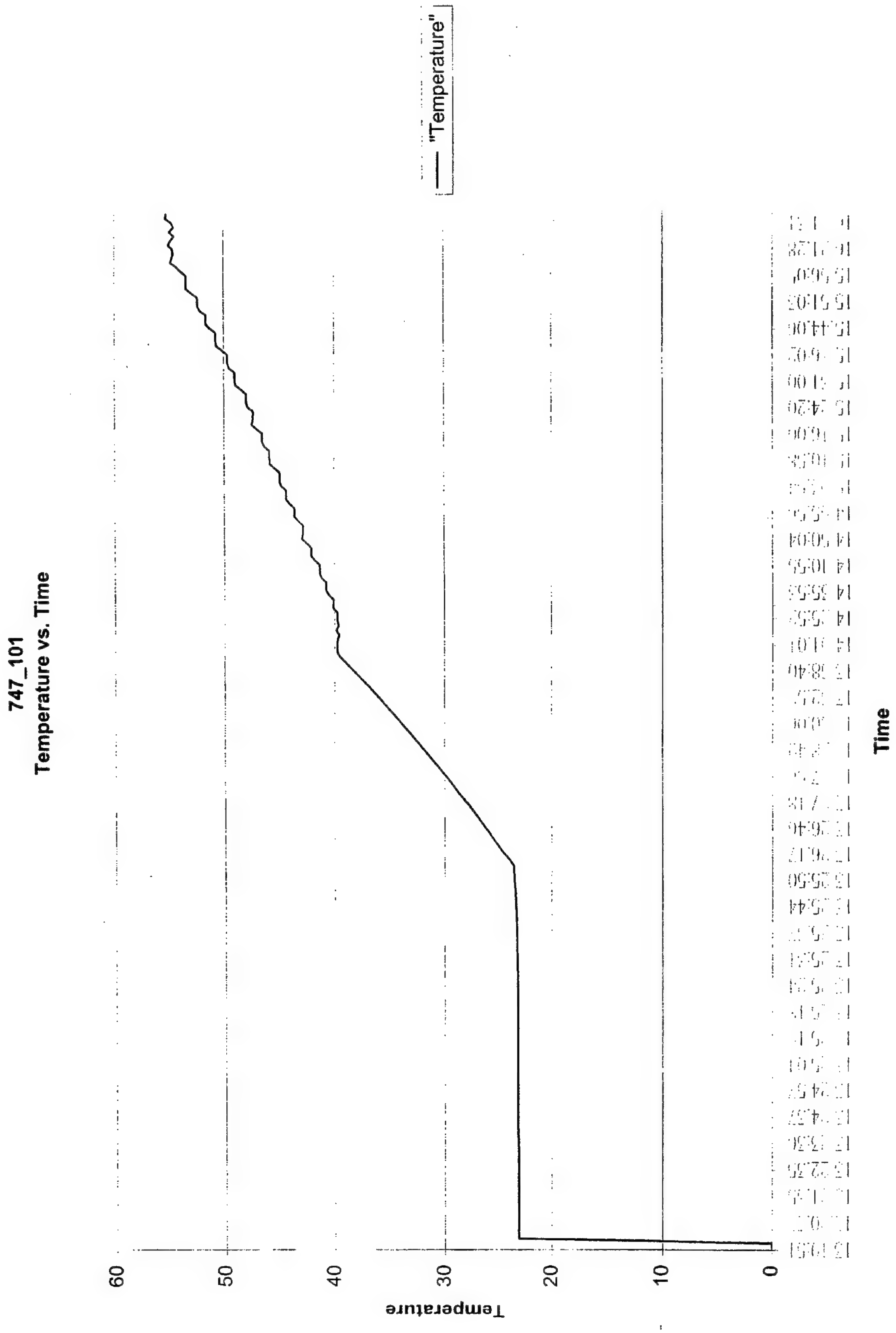


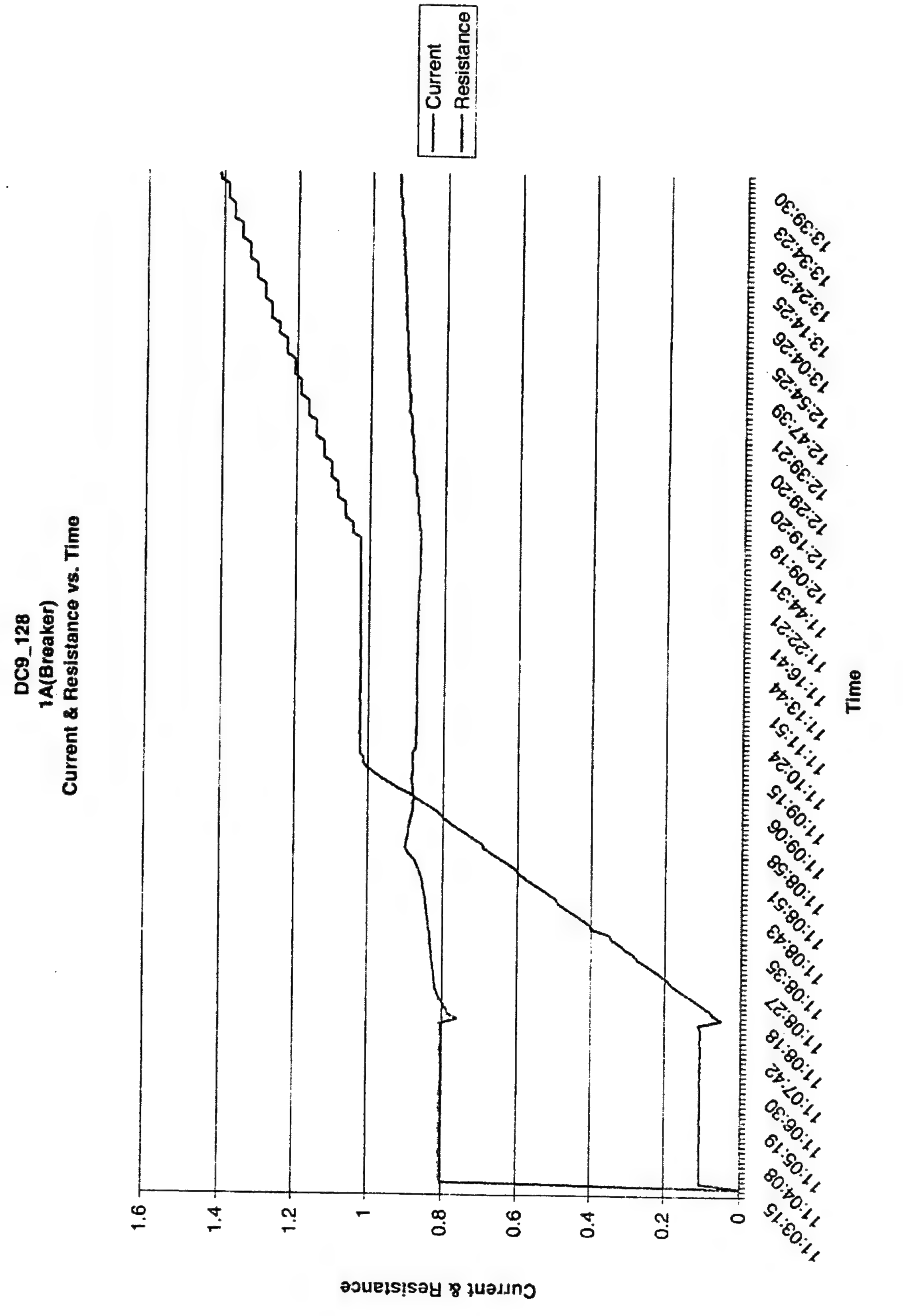
A3F9A8~1
Temperature vs. Time

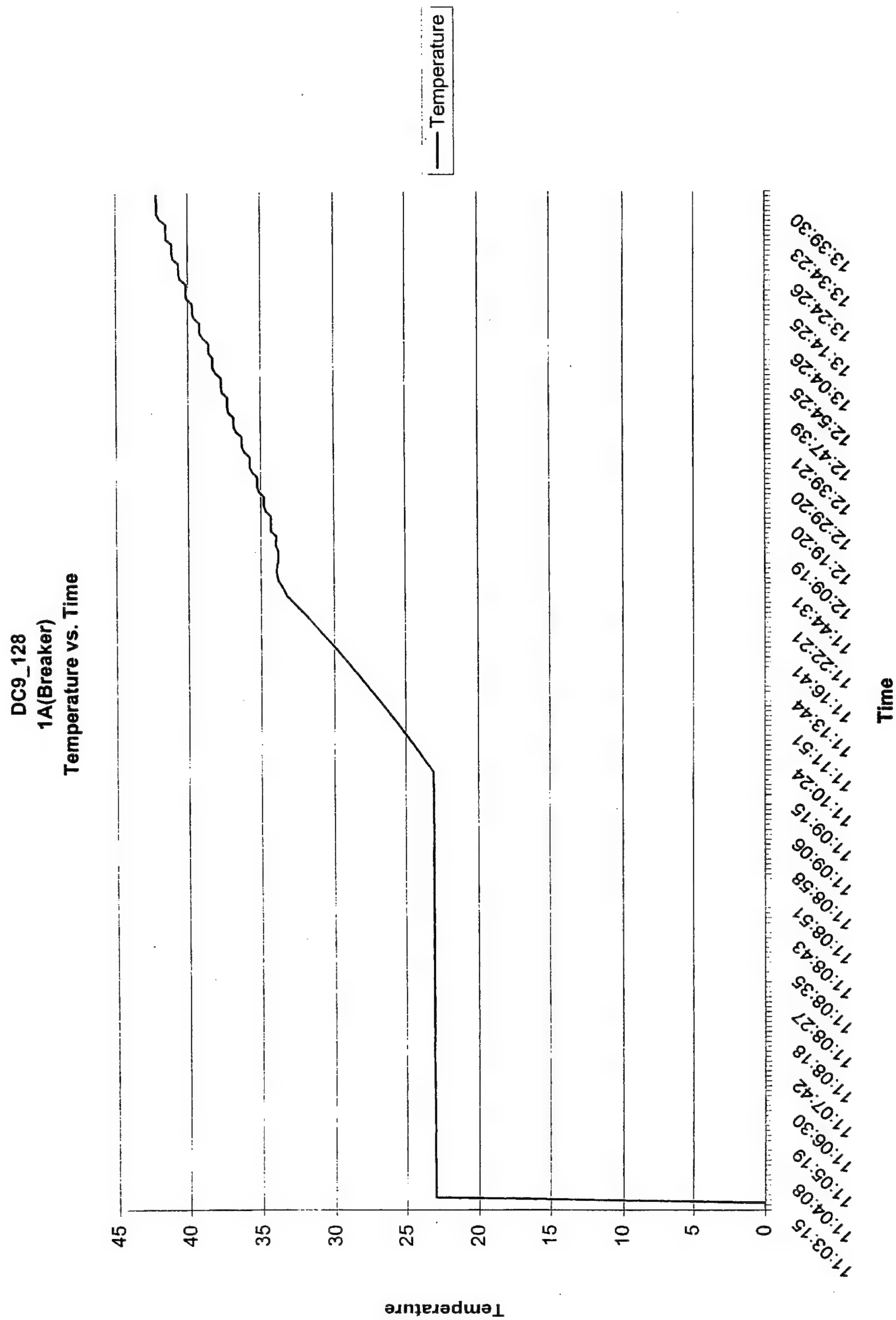




747_101
Current & Resistance vs. Time
"Current"
"Resistance"
Current & Resistance
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Time
13:19:51
13:20:33
13:21:35
13:22:35
13:23:36
13:24:37
13:24:57
13:25:04
13:25:10
13:25:18
13:25:24
13:25:31
13:25:37
13:25:44
13:25:50
13:26:17
13:26:46
13:27:18
13:27:56
13:28:49
13:30:06
13:32:52
13:38:40
14:01:01
14:25:52
14:35:53
14:40:55
14:50:04
14:55:56
15:03:54
15:10:58
15:16:00
15:24:20
15:31:00
15:36:02
15:44:06
15:51:03
15:56:05
16:21:28
16:51:31


747_101
Temperature vs. Time
"Temperature"
Temperature
Time
0
10
20
30
40
50
60


DC9_128
1A(Breaker)
Current & Resistance vs. Time
Current & Resistance
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Time
11:03:15
11:04:08
11:05:19
11:06:30
11:07:42
11:08:18
11:08:27
11:08:35
11:08:43
11:08:51
11:08:58
11:09:06
11:09:15
11:10:24
11:11:51
11:13:44
11:16:41
11:22:21
11:44:31
12:09:19
12:19:20
12:29:20
12:39:21
12:47:39
12:54:25
13:04:26
13:14:25
13:24:26
13:34:23
13:39:30
Current
Resistance



DC9_128
1A(Breaker)
Temperature vs. Time
Temperature
45
40
35
30
25
20
15
10
5
0
Time
11:03:15
11:04:08
11:05:19
11:06:30
11:07:42
11:08:18
11:08:27
11:08:35
11:08:43
11:08:51
11:08:58
11:09:06
11:09:15
11:10:24
11:11:51
11:13:44
11:16:41
11:22:21
11:44:31
12:09:31
12:19:19
12:29:20
12:39:20
12:47:21
12:54:39
13:04:25
13:14:26
13:24:25
13:34:26
13:39:23
13:39:30
— Temperature

H.2 FAA SUMMARY DATA.

FAA SUMMARY OF SANDIA LABORATORY DATA

ID	mfr	rating	test minutes	trip	current %	volts	current	resistance	bkr temp	amb temp	notes
747-100	CBMA	1	216.21	n	138%	1.003	1.41	0.7134	48.59	23.07	
747-101	CBMA	1	216.21	n	138%	1.016	1.39	0.7298	55.19	22.70	
747-102	CBMA	1	216.23	n	138%	1.012	1.39	0.7285	47.87	22.70	
747-103	CBMA	2.5	216.18	n	138%	0.407	3.45	0.1178	50.05	22.70	
747-104	CBMA	2.5	117.37	y	122%	0.401	3.08	0.1301	44.32	22.90	
747-105	CBMA	2.5	146.58	y	134%	0.392	3.37	0.1162	44.86	22.00	
747-106	CBMA	5	138.34	y	130%	0.282	6.53	0.0431	47.21	22.90	
747-107	CBMA	5	216.15	n	138%	0.295	6.94	0.0425	49.96	22.70	
747-108	CBMA	5	216.21	n	138%	0.298	6.92	0.0431	55.41	22.80	
747-109	CBMA	5	133.33	y	128%	0.267	6.42	0.0416	48.43	23.00	
747-110	CBMB	7	138.76	y	130%	0.347	9.08	0.0383	58.87	25.15	
747-111	CBMA	7.5	217.05	n	138%	0.236	10.32	0.0229	58.68	23.59	
747-112	CBMA	7.5	218.21	n	138%	-0.244	10.35	0.0235	57.79	22.94	
747-113	CBMA	7.5	134.66	y	128%	0.216	9.59	0.0225	52.02	23.60	
747-114	CBMA	10	167.96	y	138%	0.265	13.78	0.0193	70.19	23.86	very hot
747-115	CBMA	10	217.66	n	138%	0.253	13.76	0.0184	62.39	23.09	
747-101-rt	CBMA	1	216.21	n	138%	0.985	1.39	0.7079	54.73	23.03	
747-102-rt	CBMA	1	123.63	y	124%	0.912	1.25	0.7297	43.38	23.00	
747-103-rt	CBMA	2.5	216.23	n	138%	0.407	3.45	0.1177	49.93	23.04	
747-107-rt	CBMA	5	216.19	n	138%	0.287	6.94	0.0414	48.63	23.04	
747-108-rt	CBMA	5	178.55	y	138%	0.299	6.92	0.0432	55.61	23.13	
747-111-rt	CBMA	7.5	143.68	y	132%	0.247	9.87	0.0250	63.90	25.38	
747-112-rt	CBMA	7.5	217.83	n	138%	0.253	10.35	0.0244	63.81	25.82	
747-115-rt	CBMA	10	217.98	n	138%	0.254	13.77	0.0185	68.63	25.67	very hot
A300-116	CBMC	1	103.07	y	116%	1.163	1.19	0.9770	43.09	22.68	
A300-117	CBMC	1	96.27	y	114%	1.136	1.16	0.9837	42.38	22.79	
A300-118	CBMD	3	138.01	y	130%	0.340	3.92	0.0868	48.27	23.11	
A300-119	CBMD	3	113.52	y	120%	0.606	3.60	0.1681	55.01	23.14	
A300-120	CBMD	3	141.20	y	132%	0.402	4.00	0.1006	55.50	23.11	
A300-121	CBMD	3	132.08	y	128%	0.362	3.86	0.0937	52.96	23.15	
A300-122	CBMD	5	107.88	y	118%	0.345	5.93	0.0581	57.84	22.57	
A300-123	CBMD	5	126.24	y	126%	0.304	6.34	0.0479	55.41	22.59	
A300-124	CBMD	5	131.17	y	128%	0.298	6.43	0.0463	56.78	22.61	
A300-125	CBMD	5	136.80	y	130%	0.297	6.52	0.0458	55.95	22.75	
A300-126	CBMD	10	111.82	y	120%	0.205	11.98	0.0172	54.66	24.50	
A300-127	CBMD	10	15.67	y	100%	0.430	9.95	0.0433	62.51	24.03	early trip, high resistance
DC9-128	CBMA	1	156.39	y	138%	1.309	1.41	0.9284	42.17	22.72	
DC9-129	CBMA	1	136.92	y	130%	1.181	1.31	0.9000	41.24	22.60	
DC9-130	CBMA	1	216.16	n	138%	1.380	1.39	0.9937	45.40	22.42	
DC9-131	CBMA	1	216.18	n	138%	1.401	1.38	1.0118	44.84	22.42	
DC9-132	CBMA	1	146.83	y	134%	1.348	1.35	0.9940	41.49	22.53	
DC9-133	CBMA	2	131.39	y	128%	0.837	2.58	0.3248	51.88	22.59	
DC9-134	CBMC	1	147.82	y	134%	1.243	1.35	0.9233	52.92	22.53	
DC9-135	CBMC	1	216.24	n	138%	1.303	1.39	0.9393	54.38	22.99	
DC9-136	CBMC	2	116.37	y	122%	1.005	2.45	0.4102	55.66	22.54	
DC9-137	CBMB	5	218.20	n	138%	0.292	6.92	0.0422	46.93	22.53	
DC9-138	CBMC	7.5	137.34	y	130%	0.242	9.72	0.0249	55.45	24.07	
DC9-139	CBMC	10	217.23	n	138%	0.208	13.75	0.0151	58.27	23.73	
DC9-140	CBMC	10	217.55	n	138%	0.211	13.79	0.0153	57.03	23.40	
DC9-141	CBMC	10	217.72	n	138%	0.210	13.76	0.0152	50.91	23.42	
DC9-142	CBMC	10	146.35	y	132%	0.236	13.17	0.0180	56.29	23.93	
DC9-143	CBMC	15	217.67	n	138%	0.208	20.64	0.0101	66.14	23.31	

	Total Tested	Total Passed	Total Failed	1.0	2.0	2.5	3.0	5.0	7.0	7.5	10.0	15.0	Aircraft A Pass	Aircraft A Fail	Aircraft B Pass	Aircraft B Fail	Aircraft C Pass	Aircraft C Fail
CBMA	21	10	11	8	1	3		4		3	2		6	9			4	2
CBMB	2	1	1					1	1				1					1
CBMC	11	6	5	4	1					1	4	1			2		4	5
CBMD	10	10	0				4	4			2				10			
Total	44	27	17	12	2	3	4	9	1	4	8	1	7	9	12	0	8	8
														0.6		0		0.5
			Pass	6	2	2	4	6	1	2	4							
			Fail	6		1		3		2	4	1						

AIRCRAFT HISTORY	747	A300	DC-9
Aircraft Letter	A	B	C
Year of Manufacture	1973	1978	1967
Flight Hours	100000	40000	75000
Flight Cycles	20348	27078	100017
Date Retired	36281	36342	36373
Date CB Panels Removed from Aircraft	36526	36404	36465
Aircraft Wire Type	PolyX	Polyimide	PVC/Gls/ Nylon
Approximate Age When Inspected	Jan-00	Jan-00	Feb-00
Failures/flight hours	0.00009	0	0.000107
Failures/Flight Cycles	0.00044	0	8E-05
Failures/Age	0.33333	0	0.25

APPENDIX I—CIRCUIT BREAKER MANUFACTURER TO PART NUMBER CODES CROSS REFERENCE TO PART NUMBERS

Circuit Breaker Cross Reference Code

Manufacturer	Mfr PN. Code (- Amp Rating)	Mfr part nunber (- Amp rating)	Test Process 1 or 2
Texas Instruments	A -	7274-55-	1&2
	B -	7274-21-	1&2
	C-	2TC6-	2
	D-	6752-304-	2
	E-7.5	7276-13-7.5	2
	E-8	7276-13-8	2
Mechanical Products	G -	700-013-	1
	H -	700-030-	1/2
	I -	700-066-	1/2
	J -	1500-032-	1
	K -	8500-005-	1
	L -	9500-001-	1
	M -	1536-066-	2
	N -	4310-002-	2
	U-	1200-009-	2
Wood Electric	P - 15	505-215-102-	2
	P - 20	505-220-102-	2
	R - 5	492-205-102-	2
	R - 15	492-215-102-	2
	S - 50	450-250-103-	2
Texas Instruments	CBMA	Klixon	Includes Numerous Part Numbers
Mechanical Products	CBMC	Mech Prod	Includes Numerous Part Numbers
Wood Electric	CBMB	Wood Elect.	
Crouzet SA	CBMD	Crouzet	

APPENDIX J—FAA AIRWORTHINESS ASSURANCE NONDESTRUCTIVE INSPECTION VALIDATION CENTER CIRCUIT BREAKER TEST DATA

In the spring of 2000, Sandia National Laboratories performed current overload testing ranging from 100% to 138% on 52 breakers removed from three aircraft: an Airbus A300, a Boeing 747, and a McDonnell Douglas DC-9. The voltage drops and temperature rises were continuously recorded during the test. The test program is described in appendix G. The data from the Sandia testing was provided by the FAA for inclusion in this test report. Comparison of Sandia National Laboratories results with the Process 1 and Process 2 test protocol results were not performed because the test procedures used to perform the same tests were different and the performance requirements of the breakers tested were not known.

Examples of graphical representations of LVCR, temperature rise, and current rise for the breakers are provided in appendix H. The results indicated that the LVCR was relatively constant during the current rise. The results also indicated that the temperature rises followed the current rises. The results are not unexpected, since the breaker contact resistance is designed to be consistent and the breaker is designed to open as a function of temperature rise due to increased current.

A sanitized summary of the Sandia National Laboratories data, which was developed by the FAA, is also provided in appendix H. This summary includes the aircraft histories.

The results are depicted as charts in figures 1 through 7 and are described as follows:

a. Figure J-1 provides the distribution of the manufacturer's circuit breakers tested.

b. Figure J-2 provides the quantity of circuit breakers tested by current rating and manufacturer.

c. Figure J-3 provides the circuit breaker pass/fail totals for each manufacturer. It also graphically depicts the total number of breakers passing versus the total number of breakers failing.

d. Figure J-4 provides the number of pass/fail breakers as a function of current rating.

e. Figure J-5 compares the number of breakers that passed or failed for the three aircraft. Aircraft A is the B747, aircraft B is the A300, and aircraft C is the DC-9.

f. Figure J-6 compares the aircraft flight hours to flight cycles.

g. Figure J-7 compares the circuit breaker failures per flight hours, failures per flight cycle, and failures per service life (years) of the aging aircraft.

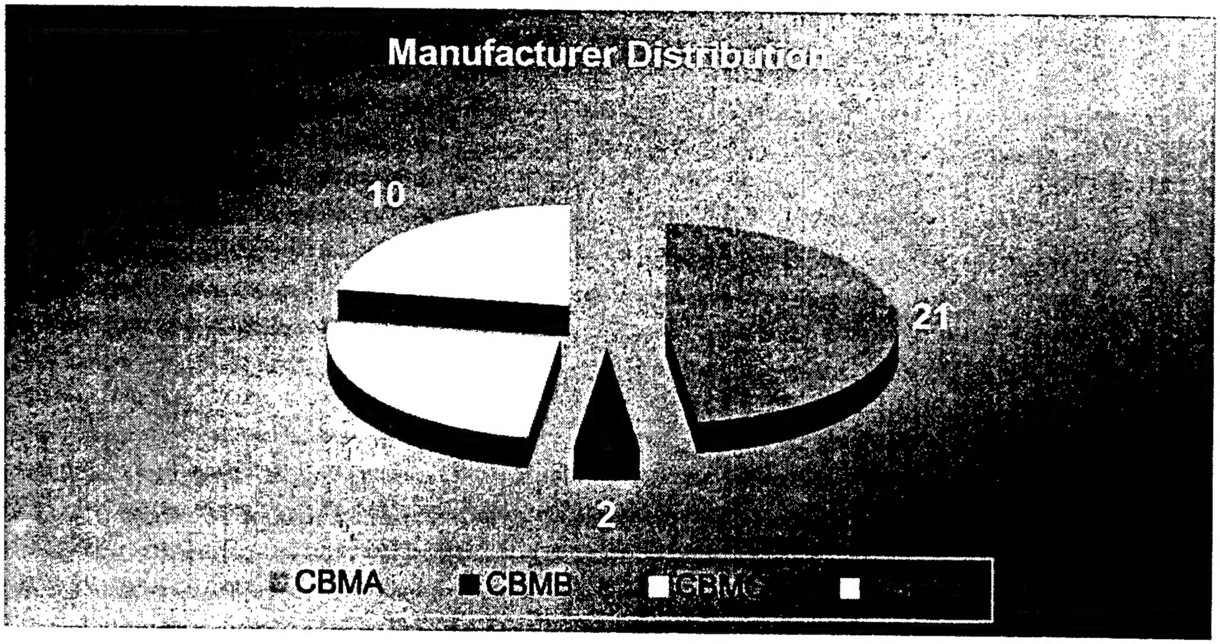


FIGURE J-1. FAA AANC SAMPLE DISTRIBUTION OF MANUFACTURER'S CIRCUIT BREAKERS

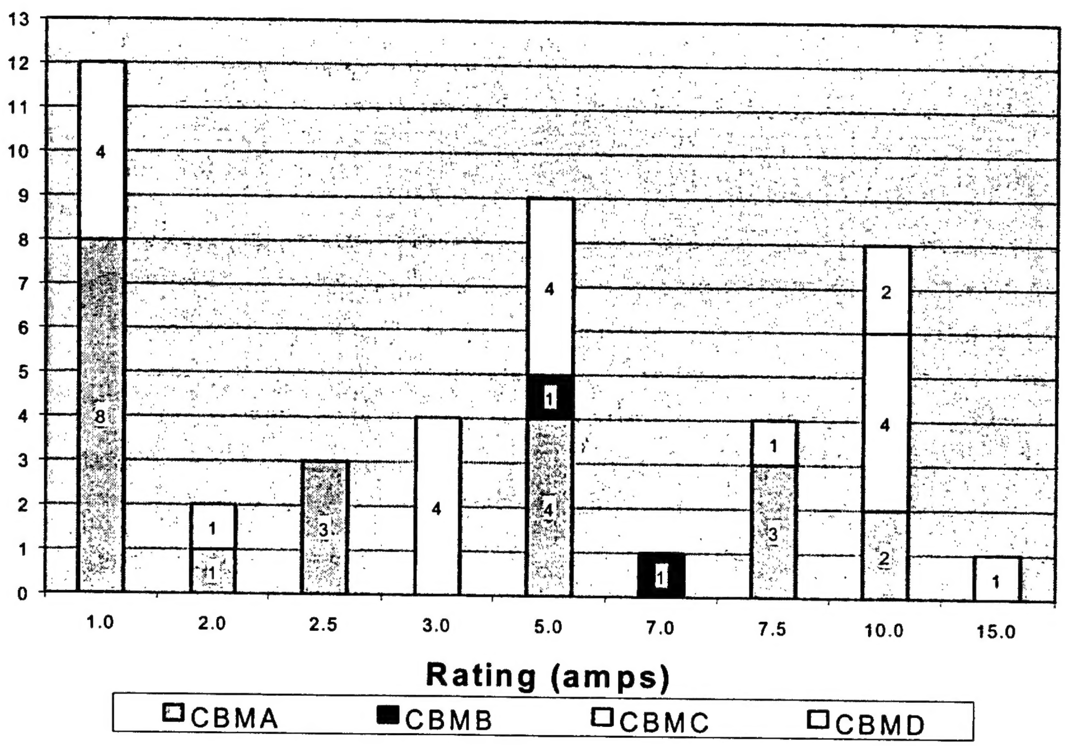


FIGURE J-2. FAA AANC CIRCUIT BREAKER SAMPLING BY AMPERE RATING AND MANUFACTURER

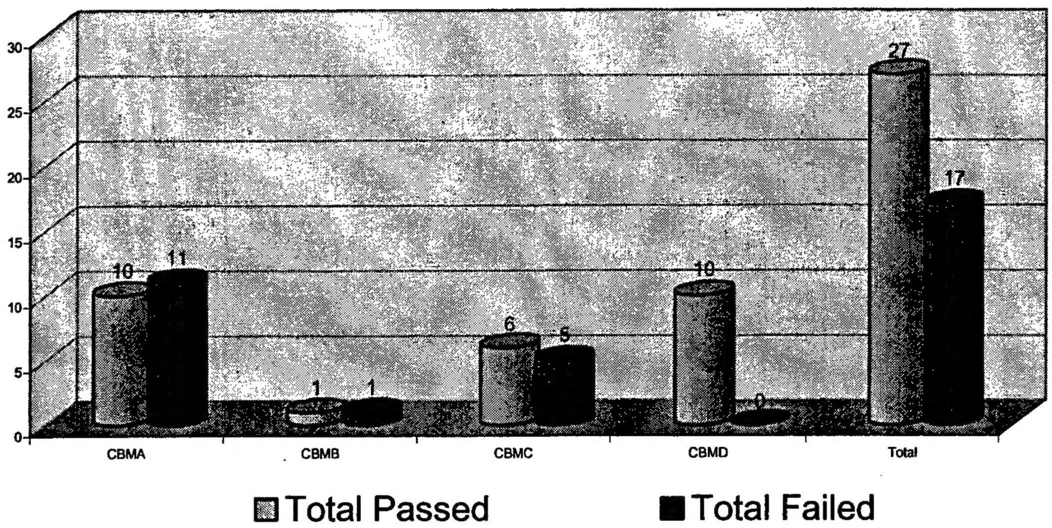


FIGURE J-3. FAA AANC CIRCUIT BREAKER TOTAL PASS/FAIL RESULTS BY MANUFACTURER

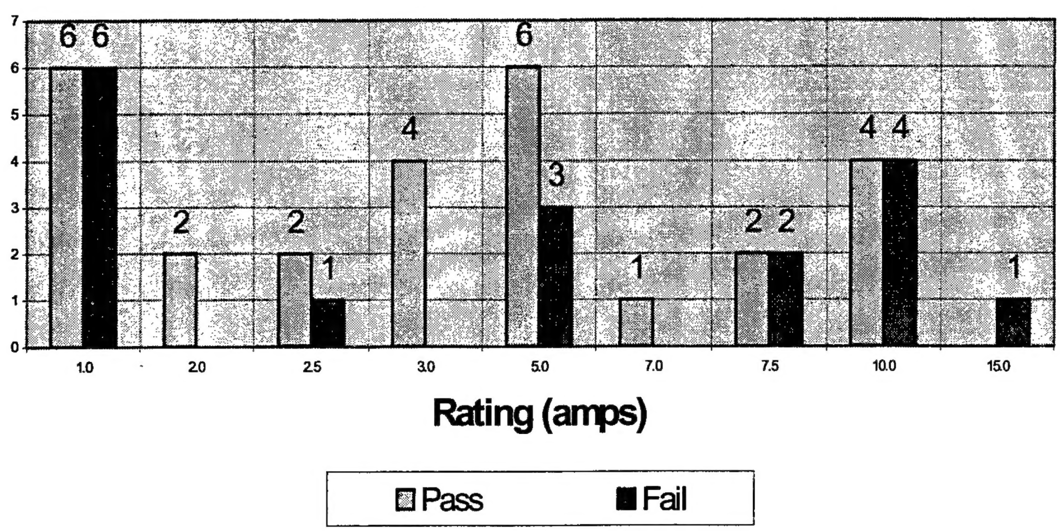


FIGURE J-4. FAA AANC CIRCUIT BREAKER PASS/FAIL RESULTS BY AMPERE RATING

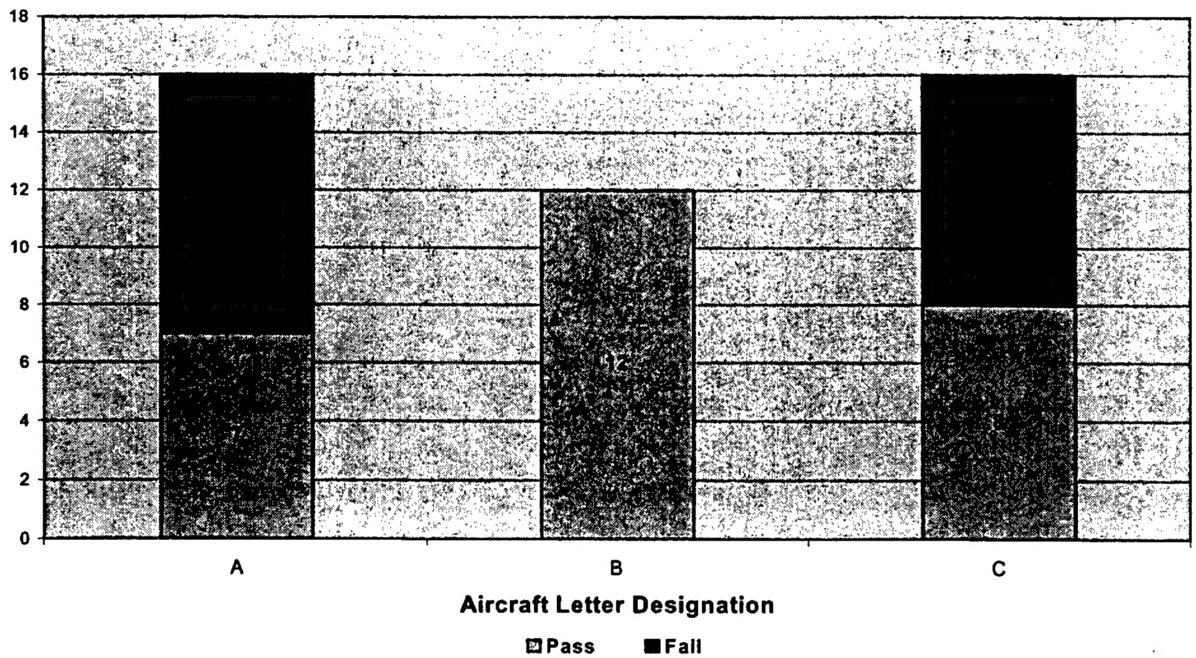


FIGURE J-5. FAA AANC CIRCUIT BREAKER PASS/FAIL BY AIRCRAFT DESIGNATION

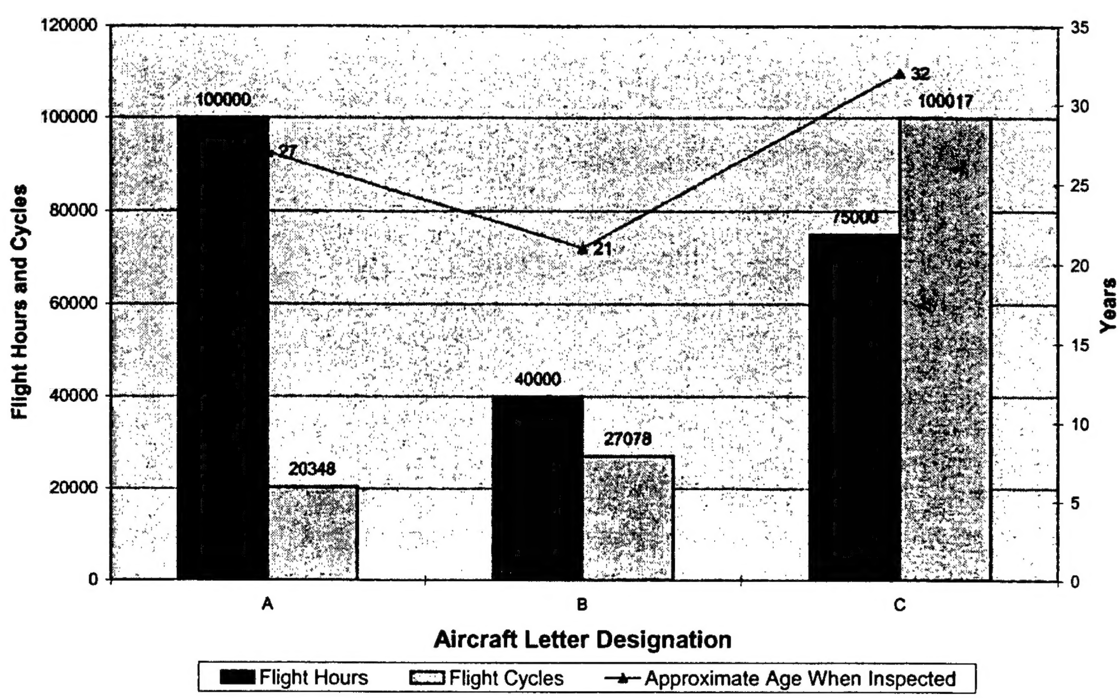


FIGURE J-6. FAA AANC AIRCRAFT FLIGHT HOURS COMPARED TO FLIGHT CYCLES INSPECTIONS

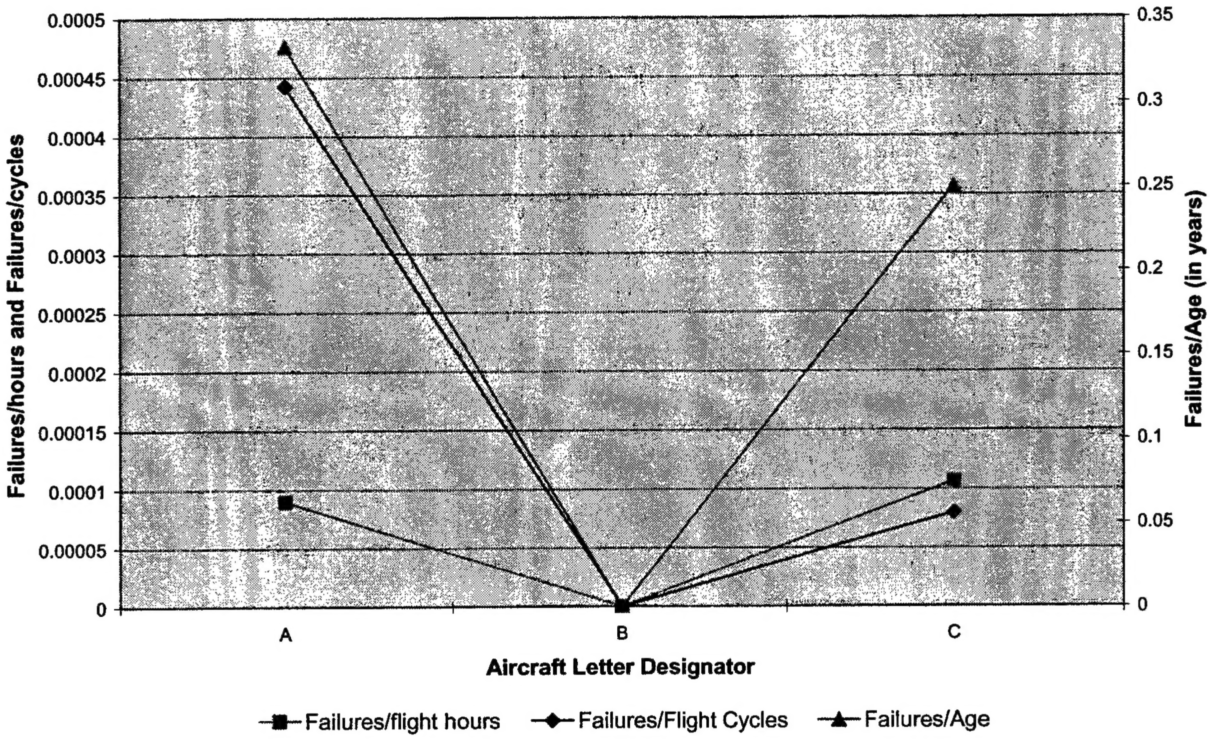


FIGURE J-7. FAA AANC CIRCUIT BREAKER FAILURES PER AIRCRAFT HOURS, CYCLES, AND AGE

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